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12

ILS GLIDE SLOPE PERFORMANCE PREDICTION MULTIPATH SCATTERING

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16. Abstract:

A mathematical model has been developed which predicts the performance of ILS glide slope systems subject to multipath scattering and the effects of irregular terrain contours. The model is discussed in detail and then applied to a test case for purposes of illustration. A complete listing of all computer programs has been appended to the report. A users' manual has been prepared under separate cover.

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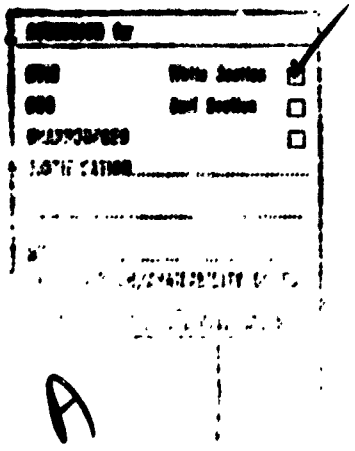
PREFACE

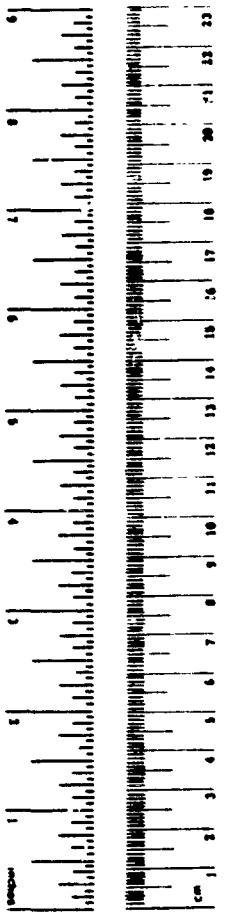
The work presented in this report has been sponsored by the Federal Aviation Administration as part of a program to provide navigational aids for the safe landing of aircraft. The program has been concerned with the application of instrument landing aids, and in particular the development of models to predict the performance of localizer and glide slope antenna systems. The present report is concerned with the glide slope portion of instrument landing system, and the effects of airport topography on its performance.



METRIC CONVERSION FACTORS

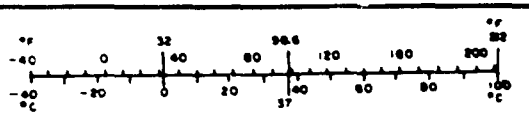
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

A mathematical model has been developed for predicting the performance of image-type glide slope arrays. The basic theory is developed in the following section of this report. In Part A of that section a model of the glide slope multipath problem is developed while in Part B the techniques for dealing with irregular terrain profiles are outlined. In the final section of the report some illustrative numerical results are presented.

2. BASIC THEORY

PART A

The presence in the airport environment of such large man-made structures as aircraft hangars as well as such natural terrain features as hillsides can lead to glide slope course derogation through multipath scattering. We begin our treatment of glide slope siting problems by developing a model for predicting the amount of such multipath derogation. A typical situation is depicted in Figure 1.

The touchdown point on the centerline of the runway opposite the glide slope array is chosen as the origin of coordinates 0. The z-axis is chosen to be the vertical axis passing through the origin 0, while the x-and y-axes are parallel to and perpendicular to the centerline, respectively. The positive z-axis points out of the page (Figure 1). The ground plane is assumed to be perfectly conducting. Consequently, any deviations from nominal glide slope performance are attributable to the multipath scattering produced by the various structures (both natural and man-made). For simplicity, we will assume that all such structures are perfectly conducting.

In the situation depicted in Figure 1, the scatterer (perhaps a small hill) is illuminated by the glide slope array and scatters

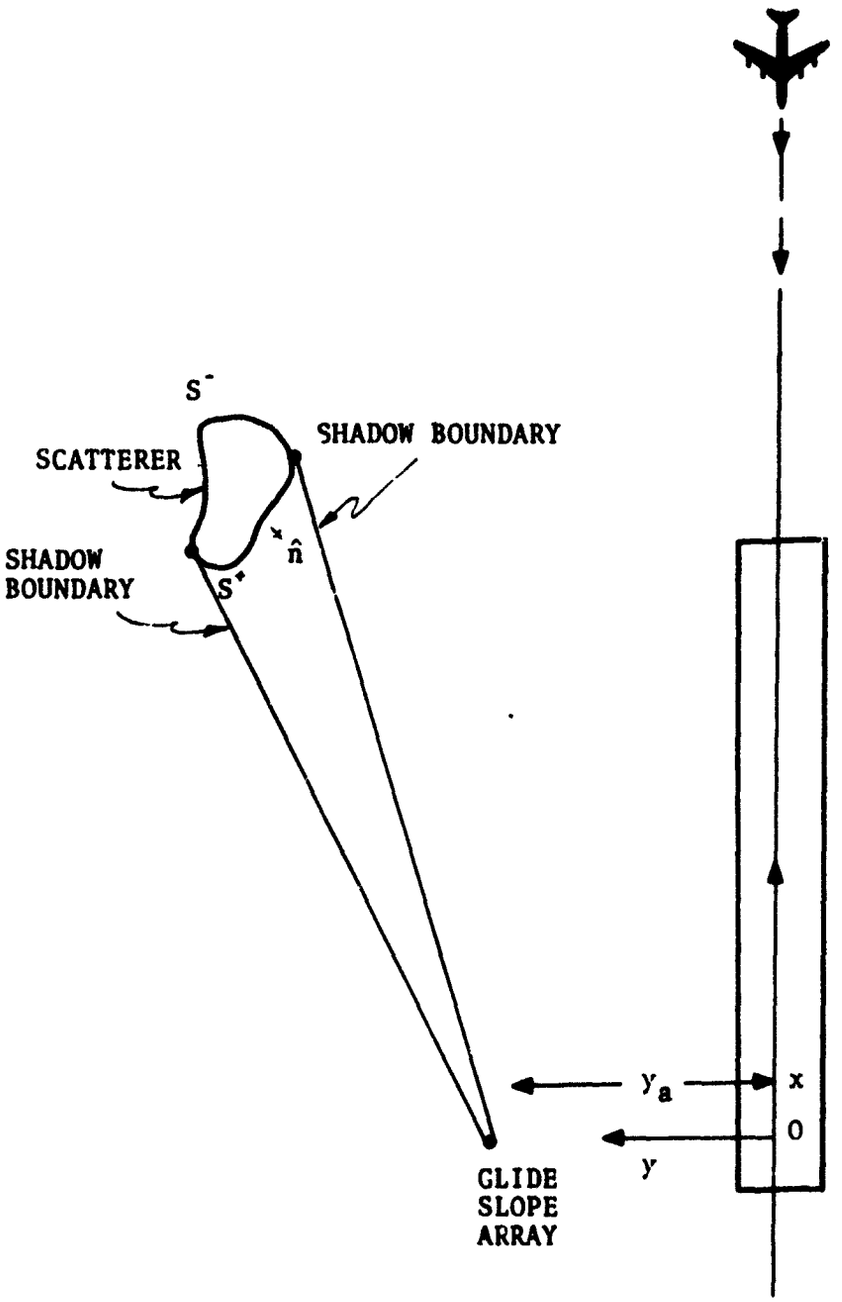


FIGURE 1. TYPICAL GEOMETRY FOR MULTIPATH SCATTERING

some of this signal back into the path of the approaching aircraft. We now proceed to calculate mathematical expressions for these scattered fields at the receiver. For convenience, we will work with magnetic field intensities.

For a perfect conductor, the surface current density K is given by:

$$\vec{K} = \hat{n} \times \vec{H} \quad , \tag{1}$$

where n is the local unit normal vector pointing out of the scattering surface and H is the total magnetic field,

$$\vec{H} = \vec{H}_i + \vec{H}_s, \tag{2}$$

where $\vec{H}_i$ is the incident and $\vec{H}_s$ the scattered field on the surface of the scattering structure. In terms of the surface current density $\vec{K}$, the scattered field $\vec{H}_s$ at the receiver is given by the following surface integral:

$$\vec{H}_s(\vec{r}_1) = \frac{1}{4\pi} \int_S \left[\vec{K}(\vec{r}) \times \vec{\nabla} G(\vec{r}_1, \vec{r}) \right] ds \tag{3}$$

In Equation (3), the vectors $\vec{r}_1$ and $\vec{r}$ denote, respectively, the position vector of the receiver and the position vector of some arbitrary source point on the surface of the scatterer relative to the origin of coordinates 0. The two-point Green's function $G(\vec{r}_1, \vec{r})$ is given by:

$$G(\vec{r}_1, \vec{r}) = \frac{e^{ik|\vec{r}_1 - \vec{r}|}}{|\vec{r}_1 - \vec{r}|} \tag{4}$$

where $k = 2\pi/\lambda$ and λ is the wavelength of the incident radiation. The integral is taken over the surface S of the scatterer.

We will adopt here the single scattering, physical optics approximation for the current density K. Specifically, we will assume that on those portions of the scattering surface not directly illuminated by the glide slope array, K is identically zero and

that on the directly illuminated portions of the scattering surface, K is proportional to twice the tangential component of the incident magnetic field:

$$\vec{K} \equiv 0 \quad \text{on } S_- \tag{5}$$

$$\vec{K} = 2\,(\hat{n} \times \vec{H}_i) \text{ on } S_+ \tag{6}$$

where S_+ and S_- denote, respectively, the illuminated and unilluminated portions of the scattering surface S (see Figure 1). For the current distribution defined by Equations (5) and (6), Equation (3) becomes.

$$\vec{H}_s(r_1) = \frac{1}{2\pi}\int_{S_+}\left[\hat{n}(\vec{r})\times\vec{H}_i(\vec{r})\right] \times \vec{\nabla} G(\vec{r}_1,\vec{r})\,ds. \tag{7}$$

The physical optics scattering model represented by equation (7) is based upon the existence of a sharp shadow boundary on the surface of the scattering structure. This assumption ignores such phenomena multiple reflections, surface waves, and diffraction but should provide reasonably accurate results as long as the surface features of the scattering structure do not vary greatly over dimensions which are small compared to the wavelength λ (about 3 feet at glide slope frequencies).

In principle, the solution to the problem at hand requires only that the magnet field H_i be determined. For simplicity, we will assume that the glide slope array is made up of electrically short dipoles. With this assumption, we in effect approximate by a cosine distribution the actual azimuthal pattern of the half-wave dipoles which make up glide slope arrays. This approximation should not be too restrictive and it does considerably expedite our calculations. Let $(0, y_a, h)$ denote the x, y, and z coordinates respectively of a typical dipole in the array and let (x, y, z) denote the coordinates of a point $\vec{r}$ at which we wish to know the magnetic field intensity H_a produced by the dipole at $(0, y_a, h)$. In our earlier

glide slope performance prediction report,* it is shown that $\vec{H}_a(\vec{r})$ is given by

$$\vec{H}_a(\vec{r}) = \frac{ikJ_o}{4\pi} \frac{e^{ikD_1}}{D_1^2} \left[x\hat{e}_z - (z-h)\hat{e}_x \right] \tag{8}$$

where $\hat{e}_x$, $\hat{e}_y$, and $\hat{e}_z$ denote unit vectors in the x, y, and z directions respectively, J_o is a parameter which measures relative phase and amplitude, and D_1 is the distance from the antenna to the observation point r:

$$D_1 = \left[x^2 + (y-y_a)^2 + (z-h)^2 \right]^{\frac{1}{2}} \tag{9}$$

To take into account reflections from the ground plane ($z = 0$) we use simple image theory to obtain the image field $\vec{H}_a^*(\vec{r})$:

$$\vec{H}_a^*(\vec{r}) = \frac{ikJ_o}{4\pi} \frac{e^{ikD_2}}{D_2^2} \left[x\hat{e}_z - (z+h)\hat{e}_x \right] \tag{10}$$

where D_2 is the distance from the image of the transmitting dipole to the field point $\vec{r}$:

$$D_2 = \left[x^2 + (y-y_a)^2 + (z+h)^2 \right]^{\frac{1}{2}} \tag{11}$$

The total field intensity H_i at $\vec{r}$ is just the sum of the direct ($\vec{H}_a$) and ground reflected ($\vec{H}_a^*$) signals:

$$\vec{H}_i(\vec{r}) = \vec{H}_a(\vec{r}) + \vec{H}_a^*(\vec{r}) \tag{12}$$

Note that on the ground plane ($z = 0$), the z component of $\vec{H}_i$ vanishes identically.

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* ILS Glide Slope Performance Predictions, Vol. B, FAA-RD-74-157.B, S. Morin, D. Newsom, D. Kahn, L. Jordan, September 1974.

The field H_i determined by Equations (8), (10), and (12) can now be substituted into Equation (7) and the integral can be performed over the illuminated surface of the scattering structure to give the scattered field at the receiver location r_1. Actually, only the z component of the scattered field need be calculated since the receiving antenna responds primarily to the horizontal component of electric field which is proportional to the z component of the magnetic field. It should be noted that for a complete solution, the contribution of the image of the scattering structure must also be calculated. We will assume that the receiver is always in the far field of the scattering structure so that the following asymptotic form of the gradient of the Green's function is applicable:

$$\vec{\nabla} G(\vec{r}_1, \vec{r}) \approx - ik\,(\vec{r}_1 - \vec{r})\ \frac{e^{ik|\vec{r}_1 - \vec{r}|}}{|\vec{r}_1 - \vec{r}|^2} \tag{13}$$

Substituting Euqations (8), (10), (12) and (13) into Equation (7) and taking the z-component of the resulting vector equation, we obtain the following expressions for $H_{sz}(r_1)$, the z-component of scattered magnetic field at the receiver point r_1:

$$H_{sz}(\vec{r}_1) = \frac{k^2 J_o}{8\pi^2} \left[I_1 + I_2 + I_3 + I_4 \right] \tag{14}$$

where

$$I_1 = \int_{S_+} \frac{F_1}{D_1^2 R_1^2}\ e^{ik(R_1 + D_1)}\ ds \tag{15}$$

$$I_2 = - \int_{S_+} \frac{F_2}{D_2^2 R_1^2}\ e^{ik(R_1 + D_2)}\ ds \tag{16}$$

$$I_3 = \int_{S_+} \frac{F_1}{D_1^2 R_2^2} \, e^{ik(R_2+D_1)} \, ds \tag{17}$$

$$I_4 = \int_{S_+} \frac{F_2}{D_2^2 R_2^2} \, e^{ik(R_2+D_2)} \, ds \tag{18}$$

$$D_1 = \left[x^2 + (y-y_a)^2 + (z-h)^2\right]^{\frac{1}{2}} \tag{19}$$

$$D_2 = \left[x^2 + (y-y_a)^2 + (z+h)^2\right]^{\frac{1}{2}} \tag{20}$$

$$R_1 = \left[(X_1-x)^2 + (Y_1-y)^2 + (Z_1-z)^2\right]^{\frac{1}{2}} \tag{21}$$

$$R_2 = \left[(X_1-x)^2 + (Y_1-y)^2 + (Z_1+z)^2\right]^{\frac{1}{2}} \tag{22}$$

$$F_1 = n_2 x (Y_1-y) + \left[n_1 x + n_3 (z-h)\right](X_1-x), \tag{23}$$

$$F_2 = n_2 x (Y_1-y) + \left[n_1 x + n_3 (z+h)\right](X_1-x) \tag{24}$$

In Equations (14) through (24), the coordinates (X_1, Y_1, Z_1) denote the coordinates of the aircraft, (x, y, z) the coordinates of some source point on the surface of the scattering structure and (n_1, n_2, n_3) the components of the unit outward normal to the surface of the scatterer at the point (x, y, z). The integrals I_3 and I_4 represent the contributions of the image of the scattering structure in the ground plane $z = 0$. Note the following relationships among the four integrals:

$$I_1 (X_1, Y_1, Z_1) = -I_3 (X_1, Y_1, -Z_1)$$

$$I_2 (X_1, Y_1, Z_1) = -I_4 (X_1, Y_1, -Z_1) \tag{25}$$

Consequently, when $Z_1 = 0$, $H_{sz}(\vec{r}_1) \equiv 0$ as it should be.

The direct numerical integration of the integrals I_1, I_2, I_3, and I_4 for an arbitrary scattering structure would in general require an inordinate amount of computer time. However, certain simplifying assumptions can be made which considerably expedite the evaluation of these integrals. Specifically, we will assume that any scattering surface can be adequately represented by a series of interconnecting plane facets. By definition, the unit normal vector $\hat{n}$ will be constant over each facet. The exact size, shape, and orientation of these facets will depend upon the surface characteristics of the particular scatterer. In turn, each facet can be broken up into a series of interconnected rectangular pieces. If these rectangular pieces are made small enough, the integrals I_1, I_2, I_3 and I_4 can be evaluated analytically for each piece and then the results summed over the whole surface of the scatterer to give H_{sz}. To illustrate these procedures, we will now evaluate the integral I_1 for an arbitrarily oriented rectangular plate. In the course of this evaluation, we will discuss the size restrictions on such plates.

In Figure 2, a rectangular facet typical of those making up the surface of some scatterer has been drawn. We will evaluate the integral I_1 of Equation (15) for such a facet in the Fraunhofer approximation. The unit vectors $\hat{\eta}$ and $\hat{\xi}$ lie in the plane of the facet, are orthonormal, and define the direction of the outward normal $\hat{n}$:

$$\hat{n} = \hat{\eta} \times \hat{\xi}$$

The center point of the facet (x_o, y_o, z_o) will be used as a local origin of coordinates for the integrations which are to be performed. The integral I_1 is given by

$$I_1 = \int_{S_+} \frac{F_1}{D_1^2 R_1^2} \, e^{ik(D_1+R_1)} \, ds \qquad (26)$$

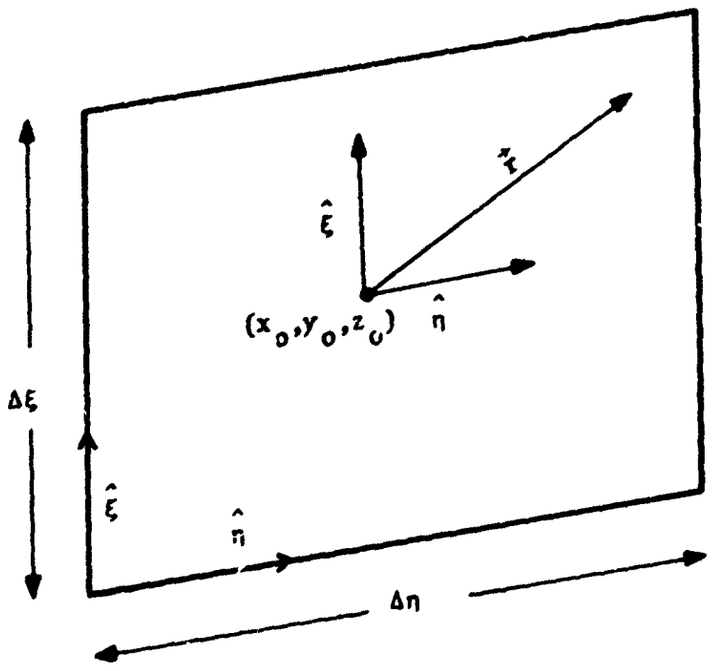


FIGURE 2. REPRESENTATION OF RECTANGULAR FACET

where

$$F_1 = n_2 \times (Y_1 - y) + \left[n_1 x + n_3 (z-h) \right] (\vec{X}_1 - x) \tag{27}$$

$$D_1 = \left[x^2 + (y-y_a)^2 + (z-h)^2 \right]^{\frac{1}{2}} \tag{28}$$

$$R_1 = \left[(X_1 - x)^2 + (Y_1 - y)^2 + (Z_1 - z)^2 \right]^{\frac{1}{2}} \tag{29}$$

Clearly, the distances D_1 and R_1 denote, respectively, the length of the vector $\vec{D}_1$ from the antenna to a point (x, y, z) on the surface of the facet and the length of the vector $\vec{R}_1$ from the point (x, y, z) to the receiver. From Figure 2, it is seen that the vector D_1 can be represented as follows:

$$\vec{D}_1 = \vec{D}_{10} + \vec{r} \tag{30}$$

where

$$\vec{D}_{10} = X_o \hat{e}_x + (y_o - y_a)\hat{e}_y + (z_o - h)\hat{e}_z \tag{31}$$

and

$$\vec{r} = \eta\hat{\eta} + \xi\hat{\xi} \tag{32}$$

and the ranges of the variables η and ξ are $-\frac{\Delta\eta}{2} \leq \eta \leq \frac{\Delta\eta}{2}$ and $-\frac{\Delta\xi}{2} \leq \xi \leq \frac{\Delta\xi}{2}$. From Equation (30), we have

$$D_1 = D_{10} \left(1 + \frac{r^2 + 2\vec{D}_{10} \cdot \vec{r}}{D_{10}^2} \right)^{1/2} \tag{33}$$

Normally, D_{10} is on the order of thousands of feet and r is of the order of tens of feet so that the radical in Equation (33) can be expanded in powers of r/D_{10} to give D_1 approximately as a function of η and ξ. To terms of second order in r/D_{10}, we obtain

$$D_1 \approx D_{10} + \eta \cos\alpha + \xi \cos\beta + \frac{r^2}{2D_{10}} - \frac{(\hat{D}_{10} \cdot r)}{2D_{10}} \tag{34}$$

where

$$\hat{D}_{10} = \vec{D}_{10}/D_{10} \tag{35}$$

$$\cos\alpha = D_{10}\cdot\hat{\eta} \tag{36}$$

$$\cos\beta = \hat{D}_{10}\cdot\hat{\xi} \tag{37}$$

The numbers $\cos\alpha$ and $\cos\beta$ are the direction cosines of D_{10} relative to $\hat{\eta}$ and $\hat{\xi}$. In the Fraunhofer approximation which we will use, it is assumed that the quatratic terms of Equation (33) are small compared to a wavelength for any point (x, y, z) on the surface of the facet so that we can write to a good approximation:

$$D_1 = D_{10} + \eta\cos\alpha + \xi\cos\beta \tag{38}$$

It can be shown that the largest value attainable by the quadratic terms in Equation (33) on the facet's surface is

$$\Delta = \frac{(\Delta\eta)^2}{8D_{10}}\sin^2\alpha + \frac{(D\xi)^2}{8D_{10}}\sin^2\beta + \frac{\Delta\eta\Delta\xi}{4}\left|\cos\alpha\cos\beta\right| \tag{39}$$

Equation (38) should provide a good approximation for the distance D_1 as a function of η and ξ as long as $\Delta\eta$ and $\Delta\xi$ are chosen so that Δ in Equation (39) is small compared to the wavelength λ. We will return to this important requirement later.

Similarly, the vector $\vec{R}_1$ can be represented as follows:

$$\vec{R}_1 = \vec{R}_{10} - \vec{r} \tag{40}$$

$$\text{where } \vec{R}_{10} = (X_1-x_o)\hat{e}_x+(Y_1-y_o)\hat{e}_y+(Z_1-z_o)\hat{e}_z \tag{41}$$

Thus, in the Fraunhofer approximation, we find

$$R_1 = R_{10} - \eta\cos\alpha - \xi\cos\delta \tag{42}$$

$$\cos\alpha = \hat{R}_{10}\,\hat{\eta} \tag{43}$$

$$\cos\beta = \hat{R}_{10}\,\hat{\xi} \tag{44}$$

where $$\hat{R}_{10} = \vec{R}_{10}/R_{10} \tag{45}$$

In Equation (42), we have ignored terms of second order and higher in r/R_{10}.

One final approximation which we will make is that $\Delta\eta$ and $\Delta\xi$ are sufficiently small compared with D_{10} and R_{10}, that the variation of the amplitude function $F_1/D_1^2R_1^2$ in Equation (26) can be ignored This is normally an excellent approximation. Consequently, we will assume that for any point on the surface of the facet we can write

$$F_1/D_1^2R_1^2 \approx F_{10}/D_{10}^2R_{10}^2 \tag{46}$$

where F_{10}, D_{10}, and R_{10}, are the values of F_1, D_1, and R_1 at the center point (x_o, y_o, z_o).

Substituting Equations (38), (42), and (46) into Equation (26) yields the following approximate expression for I_1:

$$I_1 = \frac{F_{10}}{D_{10}^2R_{10}^2}\, e^{ik(D_{10}+R_{10})} \int_{-\Delta\eta/2}^{+\Delta\eta/2} e^{ik\eta(\cos\alpha-\cos\gamma)}\,d\eta \int_{-\Delta\xi/2}^{+\Delta\xi/2} e^{ik\xi(\cos\beta-\cos\delta)}\,d\xi \tag{47}$$

Performing the integrals indicated in Equation (47), we finally obtain the following approximate expression for I_1:

$$I_1 = \frac{4F_{10}}{D_{10}^2R_{10}^2}\,\frac{e^{ik(D_{10}+R_{10})}}{k^2} \times \frac{\sin\left\{\frac{k\Delta\eta}{2}(\cos\alpha-\cos\gamma)\right\}\,\sin\left\{k\frac{\Delta\xi}{2}(\cos\beta-\cos\delta)\right\}}{(\cos\alpha-\cos\gamma)\,(\cos\beta-\cos\delta)} \tag{48}$$

A similar treatment of the integrals I_2, I_3, and I_4 ultimately lead to the following approximate expression for the scattered magnetic field intensity at the receiver due to the rectangular facet:

$$H_{sz}(\vec{r}_1) = \frac{J_o}{2\pi^2} \frac{F_{10} e^{ik(D_{10}+R_{10})}}{D_{10}^2 R_{10}^2} \frac{\sin(kA\Delta\eta/2)\sin(kB\Delta\xi/2)}{A\,B}$$

$$- \frac{J_o}{2\pi^2} \frac{F_{20} e^{ik(D_{20}+R_{10})}}{D_{20}^2 R_{10}^2} \frac{\sin(kA_1\Delta\eta/2)\sin(kB_1\Delta\xi/2)}{A_1 B_1}$$

$$- \frac{J_o}{2\pi^2} \frac{F_{10} e^{ik(D_{10}+R_{20})}}{D_{10}^2 R_{20}^2} \frac{\sin(kA_2\Delta\eta/2)\sin(kB_2\Delta\xi/2)}{A_2 B_2}$$

$$+ \frac{J_o}{2\pi^2} \frac{F_{20} e^{ik(D_{20}+R_{20})}}{D_{20}^2 R_{20}^2} \frac{\sin(kA_3\Delta\eta/2)\sin(kB_3\Delta\xi/2)}{A_3 B_3} \qquad (49)$$

where F_{10}, F_{20}, D_{10}, D_{20}, R_{10} and R_{20} denote the values of F_1, F_2 D_1, D_2, R_1, and R_2 at (x_o, y_o, z_o) and the parameters A, A_1, A_2, A_3, B, B_1, B_2, and B_3 are defined as follows:

$$A = \cos\alpha - \cos\gamma \qquad B = \cos\beta - \cos\delta \qquad (50)$$

$$A_1 = \cos\alpha_1 = \cos\gamma \qquad B_1 = \cos\beta_1 - \cos\delta \qquad (51)$$

$$A_2 = \cos\alpha - \cos\gamma_1 \qquad B_2 = \cos\beta - \cos\delta_1 \qquad (52)$$

$$A_3 = \cos\alpha_1 - \cos\gamma_1 \qquad B_3 = \cos\beta_1 - \cos\delta_1 \qquad (53)$$

and the angles appearing in Equations (50) through (53) are defined as follows:

$$\vec{D}_{10} = x_o\hat{e}_x + (y_o - y_a)\hat{e}_y + (z_o - h)\hat{e}_z \qquad (54)$$

$$\vec{R}_{10} = (X_1 - x_o)\hat{e}_x + (Y_1 - y_o)\hat{e}_y + (Z_1 - z_o)\hat{e}_z \qquad (55)$$

$$\vec{D}_{20} = x_o\hat{e}_x + (y_o - y_a)\hat{e}_y + (z_o + h)\hat{e}_z \tag{56}$$

$$\vec{R}_{20} = (X_1 - x_o)\hat{e}_x + (Y_1 - y_o)\hat{e}_y - (Z_1 + z_0)\hat{e}_z \tag{57}$$

and

$$\cos\alpha = \frac{\vec{D}_{10}}{D_{10}}\cdot\hat{\eta}\ , \quad \cos\beta = \frac{\vec{D}_{10}\cdot\hat{\xi}}{D_{10}} \tag{58}$$

$$\cos\alpha_1 = \frac{\vec{D}_{20}\cdot\hat{\eta}}{D_{20}}\ , \quad \cos\beta_1 = \frac{\vec{D}_{20}\cdot\hat{\xi}}{D_{20}} \tag{59}$$

$$\cos\alpha = \frac{\vec{R}_{10}\cdot\hat{\eta}}{R_{10}}\ , \quad \cos\delta = \frac{\vec{R}_{10}\cdot\hat{\xi}}{R_{10}} \tag{60}$$

and

$$\cos\alpha_1 = \frac{\vec{R}_{20}\cdot\hat{\eta}}{R_{20}}\ , \quad \cos\delta_1 = \frac{\vec{R}_{20}\cdot\hat{\xi}}{R_{20}} \tag{61}$$

The total scattered field at the receiver is obtained by summing up the contributions from all of the rectangular facets which make up the surface of the scattering structure. Segmenting the surface of a scatterer into rectangular facets and then applying the approximate closed form solution in Equation (49) to each facet represents a far more efficient procedure for calculating the scattered field at the receiver than attempting to directly numerically integrate Equations (14) through (18).

We now return to the question raised earlier of the size restrictions upon the facets. Clearly, one would like to maximize the area of each facet in order to minimize computer running time. The principal restriction upon the size of the facets is that $\Delta\eta$ and $\Delta\xi$ must not be so large that the Fraunhofer approximation, upon which the approximate formula (49) is based, is violated. That is, the quadratic path length difference terms like those in Equation (34)

must be small compared to the wavelength λ for all points on the surface of the facet to which Equation (49) is to be applied. Thus, in choosing appropriate values for $\Delta\xi$ and $\Delta\xi$, we are essentially faced with an optimization problem with a constraint. Specifically, we want to maximize the area $\Delta\eta\Delta\xi$ of the facet while keeping the quadratic path length difference terms less than some prescribed value. For example, for the path length D_1, the maximum value of the quadratic path length difference term is given by

$$\Delta = \frac{(\Delta\eta)^2}{8\,D_{10}}\sin^2\alpha + \frac{(\Delta\xi)^2}{8\,D_{10}} + \frac{\Delta\eta\Delta\xi}{4}\left|\cos\alpha\cos\beta\right| \qquad (62)$$

Depending upon the sign of $\cos\alpha\cos\beta$, this value will be achieved at two of the four corners of the rectangular facet At all other points, the quadratic path length terms will be less than Δ, but always positive. We can optimize our choice of $\Delta\eta$ and $\Delta\xi$ by maximizing $\Delta\eta\,\Delta\xi$ subject to the condition that Δ in Equation (62) be some fractional part of a wavelength. This problem has been solved in closed form using Lagrange multipliers. The optimization procedure must be applied to the quadratic path length difference terms affecting all four distances (D_1, D_2, R_1, R_2) and then from the resulting set of solutions the smallest values of $\Delta\eta$ and $\Delta\xi$ are chosen. . subroutine has been written to carry out the optimization procedure.

Of course, the scattered fields must be calculated for each dipole in the array, the parameter J_o being varied to take into account the exact phase and amplitude ratios among the various elements and, along with J_o, the height h and y-offset y_a of each element. Our program automatically offsets the elements of an array to correct for the effects of proximity phase lag. The y-coordinates of the elements are adjusted so that all dipoles are at the same slant distance from the touchdown point on the runway directly opposite the array.

Once all of the scattered fields have been calculated, the calculation of the difference in depth of modulation (D.D.M) at a given receiver location is straight forward. The scattered fields at the carrier frequency, 90Hz modulated frequency, and 150Hz modulated frequency are first added to the direct fields at those frequencies. By direct fields is meant the fields which would exist if the scatterers were not present. For example, if the ground plane is perfectly flat, the direct field for any one of the three frequencies at the receiver location r_1 is just the z component of Equation (12).

$$H_{iz}(\vec{r}_1) = \frac{ikJ_o}{4\pi} X_1 \left[\frac{e^{ikD_1}}{D_1^2} - \frac{e^{ikD_2}}{D_2^2} \right] \tag{63}$$

where, here, D_1 and D_2 denote, respectively, the distance from the antenna to the aircraft and the distance from the image antenna to the aircraft, and X_1 is the x coordinate of the aircraft. If the ground plane is not perfectly flat or at least nearly so the direct fields are calculated differently. These alternate procedures will be discussed in the next section. In any case, once the total complex field amplitudes (direct plus scattered summed for all dipoles in the array) have been found, the DDM is calculated as follows: let H_c, H_{150}, and H_{90} denote the total complex amplitudes at the carrier frequency, the 150 Hz modulated frequency, and the 90 Hz modulated frequency. In terms of these complex amplitudes, the difference in depth of modulation is given by:

$$\text{D.D.M.} = \text{Re}\left(\frac{H_{150} - H_{90}}{H_c} \right) \tag{64}$$

where Re denotes the real part of the complex number. Full scale deflection (150 microamps) corresponds to a D.D.M. of .175 for the glide slope. Consequently, the C.D.I. (course deviation indication) is given by

$$\text{C.D.I.} = 857.14\ \text{Re}\left(\frac{H_{150} - H_{90}}{H_c} \right) \text{microamps} \tag{65}$$

PART B

In Part A of this section, we developed techniques for estimating glide slope performance degradation due to multipath scattering. Once the scattered fields produced by the various scattering structures in the airport environment have been calculated, they are added to the direct fields at the corresponding frequencies and from these total fields, the C.D.I. is calculated using Equation (65). The direct field at the particular frequency is just the field which would be detected at the receiver in the absence of the scattering structures. If the ground plane is otherwise perfectly flat or nearly so, the direct field is given according to simple image theory by Equation (63).

$$H_{iz} = \frac{ikJ_o}{4\pi} X_1 \left[\frac{e^{ikD_1}}{D_1^2} - \frac{e^{ikD_2}}{D_2^2} \right] \tag{63}$$

where D_1 and D_2 are, respectively, the distance between the receiver and the transmitting dipole and between the receiver and the image of the dipole. On the other hand, if the terrain profile exhibits significant irregularities such as downgrade; or drop offs along the line of sight between the aircraft and the antenna mast, Equation (63) cannot be used and the techniques developed in our earlier glide slope performance prediction model must be used.

In the report ILS Glide Slope Performance Prediction, Vol. B (FAA-RD-74-157.B), we developed mathematical procedures for calculating the ground reflected signals resulting from irregular terrain profiles such as the one depicted in Figure 3. The detailed calculations will not be repeated here, However, the updated computer program contains the subroutines for performing these calculations. One simply inputs the shape of the terrain profile along the line of sight between the aircraft and the antenna mast, and the subroutines

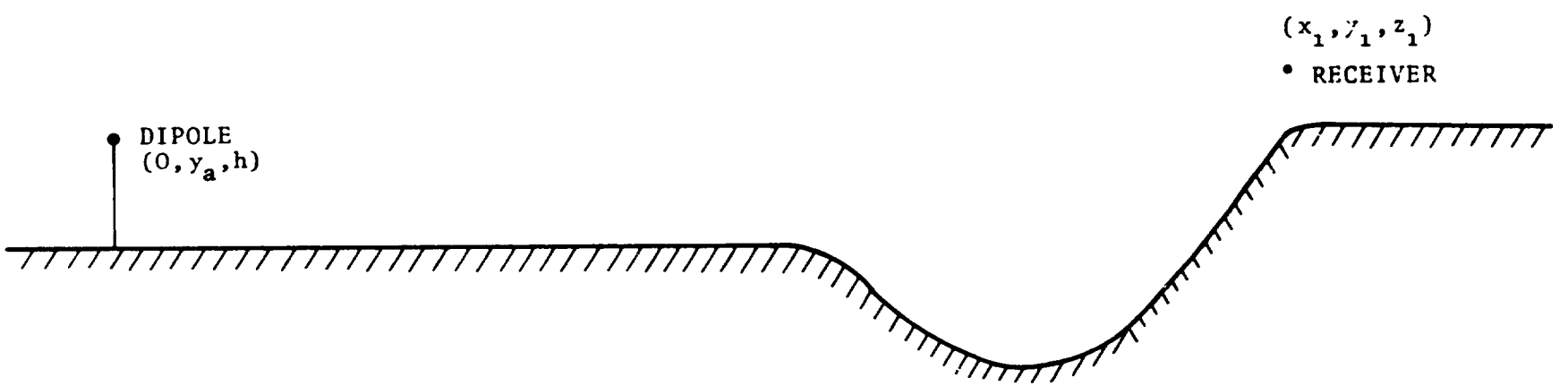


FIGURE 3. TYPICAL PROFILE OF ONE-DIMENSIONAL TERRAIN VARIATION

will generate the ground reflected signals at the carrier frequency. 90Hz modulated frequency, and the 150Hz modulated frequency. These signals are then combined with the incident signals directly from the antennas to give what we have been calling the direct fields, the fields which would be measured at the reeeiver assuming that no scatterers (hangars, hillsides, etc.) were present. These direct signals are then combined with the scattered signals calculated using the techniques of Part A and the resulting total signals are used in Equation (65) to calculate C.D.I. Again, if the terrain profile is perfectly flat or nearly so, Equation (63) can be used to calculate the direct signals.

3. NUMERICAL RESULTS

Before presenting some sample numerical results illustrating the predictions of our model, we will first review the characteristics of the three main types of image glide slope arrays; the null reference, the sideband reference, and the capture effect arrays.

The null reference array is the simplest of the image glide slope systems. It consists of two transmitting antennas whose heights are in the ratio of 2:1. The upper antenna is fed sideband only signal, the 150 Hz and the 90 Hz components being of equal amplitude but 180° out of phase. The lower antenna is fed both carrier and sideband. The carrier signal is nominally 40% modulated. The ratio of the sideband currents in the upper antenna to the sideband currents in the lower antenna is typically 0.3. The sideband ratio of 0.3 would nominally yield a 1.4° course width (full deflection 0.7° above or below the glide path). Let

I_c, I_{150}, and I_{90} denote the current amplitudes fed to the antennas at the carrier frequency, the 150 Hz modulated frequency, and the 90 Hz modulated frequency, respectively. The null reference array parameters discussed above can be summarized as follows:

Carrier Antenna	Sideband Antenna
Height = h	Height = 2h
$I_c = 1$	$I_c = 0$
$I_{150} = 0.4$	$I_{150} = 0.12$
$I_{90} = 0.4$	$I_{90} = -0.12$

Note that all current amplitudes have been normalized relative to the carrier current amplitude ($I_c = 1$).

The sideband reference array employs two transmitting dipoles whose heights are in the ratio of 3:1. If the lower ntenna is positioned at 1/2 the height of the lower antenna of the null reference array and if the upper antenna is positioned at 3/4 of the height of the upper antenna of the null reference array, the same glide angle is produced. Modulated carrier (40% modulated) is fed to the lower antenna. Both antennas are fed separate sideband signals. The separate sideband signals fed to the two antennas are equal in amplitude but are 180° out of phase. The amplitude ratio of the separate sideband signal to the carrier sideband signal is typically 0.3. This ratio produces a nominal course width of 1.4° as in the case of the null reference array. The sideband reference parameters are summarized below.

Lower Antenna	Upper Antenna
Height = h	Height = 3h
$I_c = 1$	$I_c = 0$
$I_{150} = 0.28$	$I_{150} = 0.12$
$I_{90} = 0.52$	$I_{90} = -0.12$

Note that the I_{150} and I_{90} current amplitudes given above for the lower antenna represent the sums of the carrier sideband and separate sideband signals (I_{150} = .4 - .12 = .28, I_{90} = .4 + .12 = .52). All current amplitudes have been normalized relative to the carrier signal amplitude.

The capture effect glide slope array consists of three transmitting antennas whose heights are in the ratios of 1:2:3. If the lower and middle antennas are set at the same heights as the null reference antennas, the same glide angle is produced. We will not treat the clearance signal which provides a [illegible] fly up signal at low approach angles but has little effect upon the glide angle and course width. Concerning the primary signal, the modulated carrier is fed to both the lower and middle antennas. The modulated carrier fed to the middle antenna has half the amplitude and is 180° out of phase with the modulated carrier fed to the lower antenna. The carrier signals are nominally 40% modulated. In addition, all three antennas are fed separate sideband signals. The separate sideband signals fed to the lower and upper antennas have half the amplitude and are 180° out of phase with the separate sideband signal fed to the middle antenna. The ratio of the separate sideband signal fed to the middle antenna to the carrier sideband signal in the lower antenna is typically 0.3. This ratio yields nominally a course width of 1.4° as in the case of the null reference array. The capture effect array parameters are summarized below.

Lower Antenna	Middle Antenna
Height = h	Height = 2h
I_c = 1	I_c = -0.5
I_{150} = 0.34	I_{150} = -0.08
I_{90} = 0.46	I_{90} = -0.32

Upper Antenna
Height = 3h
I_c = 0
I_{150} = -0.06
I_{90} = 0.06

Note that the I_{150} and I_{90} current amplitudes given above represent the sums of the carrier sideband and separate sideband signals. Again, all values have been normalized relative to the carrier amplitude in the lower antenna.

It should be noted here that our computer program automatically offsets the elements of each glide slope array to correct for the effects of proximity phase lag. The y coordinates of the elements are adjusted so that all dipoles are at the same slant distance from the touchdown point on the runway directly opposite the array. For each array, one element is held fixed while the other elements are offset relative to the fixed one. For the null reference and sideband reference arrays, the lower element is held fixed while for the capture array, the middle element is held fixed. The amount of the offset for each dipole can be calculated approximately in the following manner. Let y_a and h denote, respectively, the y-coordinate and height of the fixed antenna element. The y-displacement, ϵ, of any other element in the array relative to the fixed one is given approximately by:

$$\epsilon = \frac{h^2 - H^2}{2y_a} \tag{66}$$

where H is the height of the element which is to be offset.

For the present study, the wavelength λ was set at 3 feet. All arrays were positioned 300 feet from the centerline of the runway. The heights of the array elements were set at 14.33 feet and 28.66 feet (approximately 5λ and 10λ) for the null reference array, 7.17 feet and 21.5 feet (approximately 2.5λ and 7.5λ) for the sideband reference array, and 14.33 feet, 28.66 feet, and 42.99 feet (approximately 5λ, 10λ, and 15λ) for the capture effect array. Under normal circumstances, a glide angle of 3° would be produced by all three arrays.

To illustrate the performance of our multipath model, the glide slope course deragation caused by a large, flat reflecting surfaee (perhaps the side of a large hangar or the side of a hill) has been calculated. The structure was taken to be 300 feet long and 100 feet high and was oriented parallel to the runway centerline. The structure was positioned 200 feet from the runway centerline in the y-direction, on the opoosite side of the centerline from the glide slope array. The near edge of the structure was displaced 1000 feet in the x-direction from the touchdown point. The geometry of the configuration is depicted in Figure 4.

In Figures 5, 6, and 7 are plotted the C.D.I. signal as a function of the horizontal distance from touchdown for each of the three arrays for the arrangement depicted in Figure 4. In each case, the receiver followed the nominal 3^{o} zero C.D.I. hyperbola. The results for all three arrays are very similar. Our model predicts large high frequency, alternating fly up and fly down signals near the end of the flight path roughly between 1700 feet and 1800 feet from touchdown. This region in fact corresponds almost exactly to the region of specular reflection as predicted by geometrical optics. Note that the excursions are large enough to saturate the receiver over much of the affected range (full scale deflection = 150 microamps). The excursions are clearly highly localized and damp out very rapidly as the aircraft leaves the specular reflection zone. The narrowness of the pattern (i.e., the lack of broadening due to diffraction and the rapid damping of the side lobes) is undoubtedly attributable to the large size of the scatterer relative to the scattering wavelength.

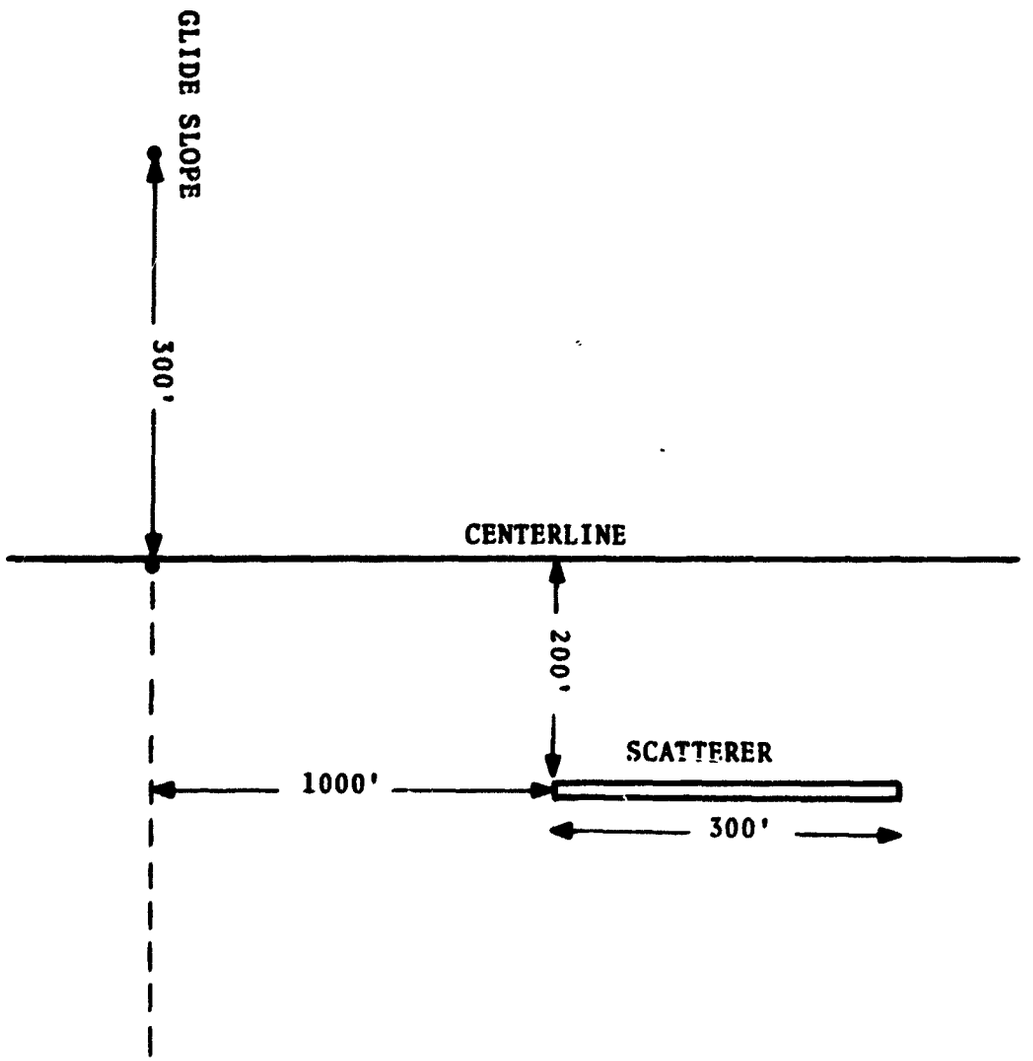


FIGURE 4. OVERVIEW OF A MULTIPATH CONFIGURATION

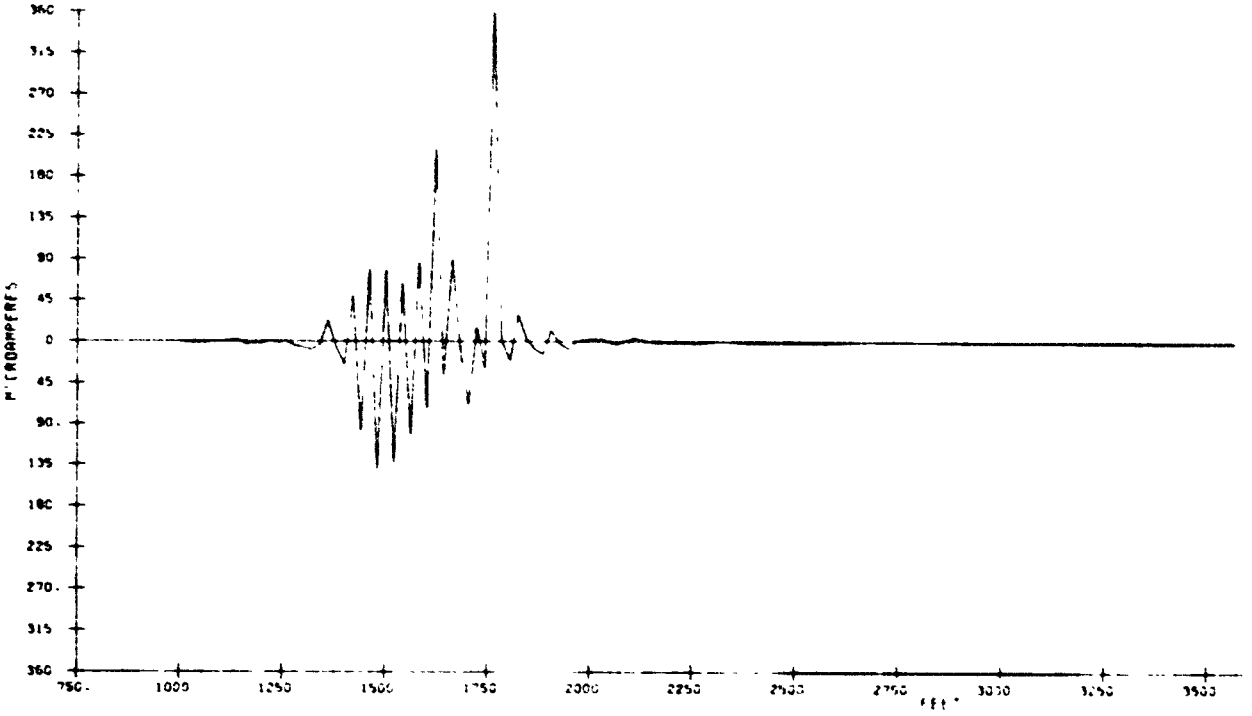


FIGURE 5. NULL REFERENCE ARRAY, FLYABILITY RUN

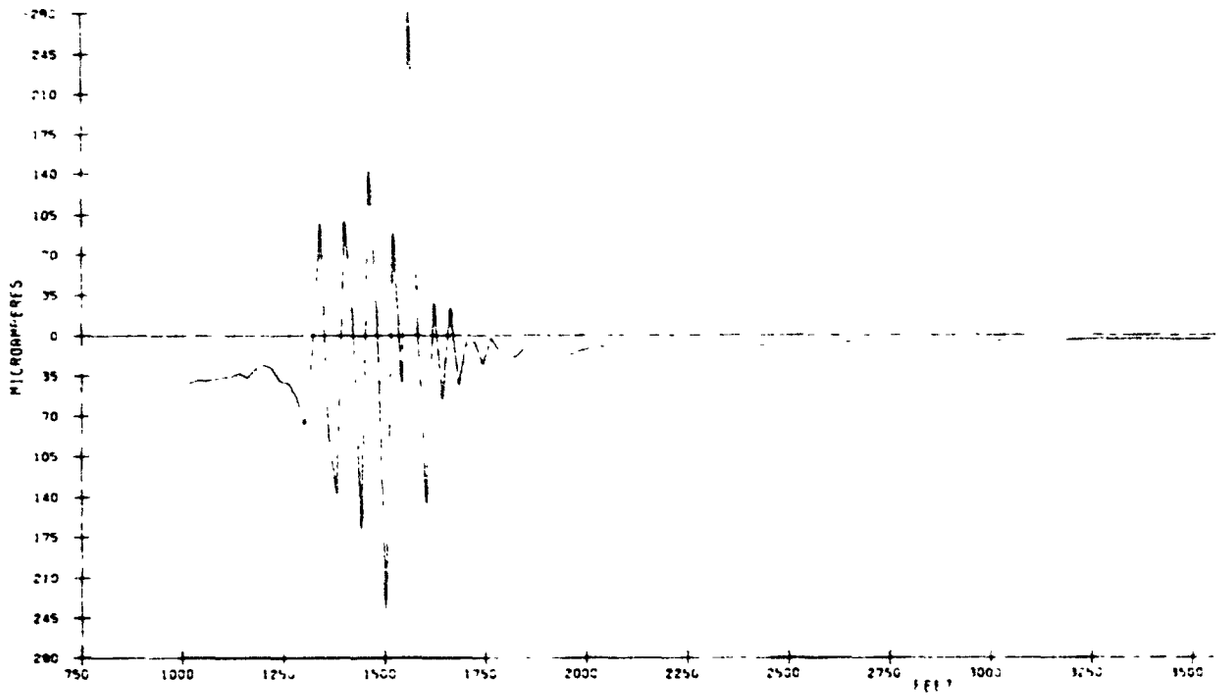


FIGURE 6. SIDEBAND REFERENCE ARRAY, FLYABILITY RUN

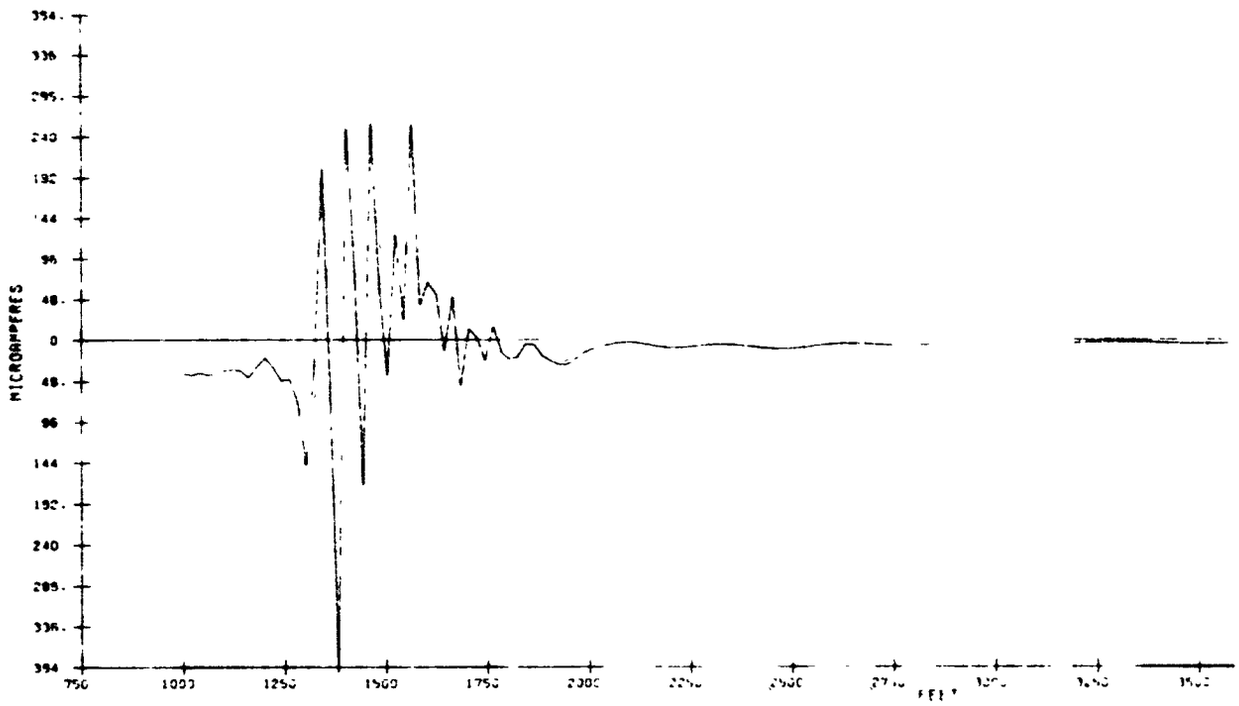


FIGURE 7. CAPTURE EFFECT ARRAY, FLYABILITY RUN

PROG`AM ILSVEN.F4

```
      DIMENSION ILABL(8)
      DIMENSION IPTDAT(33)
      COMMON /PLOT/ NRP,RXMN,RXMX,RXFT,RXLT,RYMN,RYMX,RYFT,RYLT,
     1RZMN,RZMX,RZFT,RZLT,RTMN,RTMX,RTFT,RTLT,
     2AIMN,AIMX,AIFT,AILT,ARMN,ARMX,ARFT,APLT,
     3ADIN,ADIX,ADIF,ADIL,
     4ADRN,ADRX,ADRF,ADRL
      EQUIVALENCE (IPTDAT(1),NRP)
      IMPLICIT COMPLEX (C)
      DIMENSION X(20),Y(20),Z(20)
      DIMENSION CF1(20),CF2(20),CF3(20)
      IMPLICIT DOUBLE PRECISION (D)
      COMMON /REC/RX,RY,RZ,RT,NSIZE
      REAL LAMBDA
      COMMON /GROUND/ K,X1(20),Z1(20),X2(0/20),Z2(0/20),IEL
      COMMON /ANT/AX,AY,AZ,LAMBDA,DAK,DPI
      COMMON /VAL/ HR,HI
C
C       THIS VALUE OF TWO PI IS INITIALIZED THIS WAY TO AVOID USING
C BLOCK DATA
      DPI=6.28318530717959864769
C
C       THIS OPENS THE OUTPUT FILE
      CALL OFILE(1,'STRIP')
C
C       THIS SUBROUTINE OPENS THE FLIGHT PATH FILE AND RETURNS WITH
C THE FLIGHT PATH PLOT LABEL (ILABL) AND TIME CONSTANT (TAU)
C THE FILE WAS SET UP WITH JOVMAX SO THIS SUBROUTINE AND INPUT ARE
C USED TO FACILITATE MODIFACTIONS
      CALL IF(ILABL,TAU)
 1000 FORMAT(8A5,F)
      WRITE(1,1000) ILABL,TAU
C
C       THIS SECTION INITIALIZES SOME CONSTANTS
      NRP=0
C
C       THIS SECTION INPUTS THE GROUND STRIP DESCRIPTIONS
      CALL IFILE(20,'GRND')
      READ(20,1000) ILABL
      WRITE(1,1000) ILABL
      READ(20) K,X1,Z1,X2,Z2
      CALL RELEAS (20)
C
C       THIS SECTION INPUTS THE ANTENNA FILE NAME TO BEUSED
C AND THEN INPUTS THE ANTENNA ELEMENT DESCRIPTIONS
      WRITE(5,2001)
 2001 FORMAT(' INPUT ANTENNA FILE NAME:',$)
      READ(5,2000) ILABL
 2000 FORMAT(A5)
      CALL IFILE(20,ILABL)
      READ(20,1000) ILABL
      WRITE(1,1000) ILABL
      READ(20) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
```

```
      WRITE(1) LAMBDA,NEL,(X(I),Y(I),Z(I),CFR1(I),CFR2(I),CFR3(I),I=1,NEL)
      CALL RELEAS (20)
      SQRT2L=1./SQRT(2.*LAMBDA)
      TEMP2=2*LAMBDA
      DAK=DPI/DBLE(LAMBDA)
      SAK=SNGL(DAK)
C
C       THIS IS THE MAIN LOOP FOR THE SIMULATION.  THE RECEIVER
C LOCATION IS READ IN BY INPUT.  THE DATA IS :  INPUT 'REC'
C THE INPUT BEING DONE BY JOYMAX.  IF THERE ARE  1 MORE RECEIVER
C POINTS THE SUBROUTINE RETURNS TO 200.
201   CALL INPUT(&200)
C
C       THIS SECTION INITIALIZES THE COMPLEX AMPLITUDES FOR
C THE RECEIVED FIELD AS FOLLOWS:
C       CFR1    CARRIER WITH 'REAL' GROUND
C       CFR2    150 MZ SIDEBAND WITH 'REAL' GROUND
C       CFR3    90MZ SIDEBAND WITH 'REAL' GROUND
C       CFS1    CARRIER WITH 'IDEAL' FLAT GROUND PLANE
C       CFS2    150MZ WITH 'IDEAL' GROUND
C       CFS3    90 MZ WITH 'IDEAL' GROUND
      CFR1=(0.,0.)
      CFR2=(0.,0.)
      CFR3=(0.,0.)
      CFS1=(0.,0.)
      CFS2=(0.,0.)
      CFS3=(0.,0.)
      R2=SQRT(RX*RX+RZ*RZ)
C
C       THIS LOOP IS OVER THE ELEMENTS OF THE ANTENNA
C THE COMPLEX FIELDS ARE SUMMED IN CFR1,CFR2 ETC.
      DO 3 IEL=1,NEL
C
C       THESE ARE THE LOCATION COORDINATES OF THE ANTENNA ELEMENTS
C AND CONSTANTS USED IN THE STRIP INTEGRATION
      AX=X(IEL)
      AY=Y(IEL)
      AZ=Z(IEL)
      DELX=RX-AX
      DELY=RY-AY
      DELZ=RZ-AZ
      DR=DSQRT(DELX*DELX+DELY*DELY+DELZ*DELZ)
      R=SNGL(DR)
      DR=DR*DAK
      IL=DR/DPI
C
C       THIS SECTION INITIALIZES  RR AND RI TO INCLUDE THE
C SEMI-INFINITE PEAK GROUND PLANE
      TEMP2=DR-DBLE(FLOAT(IL))*DPI
      TEMP=R2*AZ
      F1=SQRT(TEMP*TEMP+AY*AY)
      F2=-RX*TEMP/(R2*F1)
      FC=SQRT(1.-AY*AY/(TEMP*TEMP))
```

```
      TD=TC*AZ
      R1=R2*TC
      S=SQRT((1./R2+1./AZ)/(TC*TC*TC))
      G=RZ/(TD*TD*R1*R1*S)
      TEMP=SAK*F1
      SF=SIN(TEMP)
      FC=COS(TEMP)
      TEMP=AZ*G/DAK/F2
C
C       HR AND HI ARE THE REAL & IMAGINARY PARTS OF THE COMPLEX
C *GAIN* FACTOR OF THE GROUND SURFACE SCATTERING TO THE RECEIVER
C LOCATION
      HR=-TEMP*(SF*FC/(DAK*TD))
      HI=TEMP*(FC-SF/(DAK*TD))
C
C       THIS SUBROUTINE SUMS THE *GAIN* FACTOR FOR EACH STRIP OF
C THE GROUND SURFACE
      CALL SCAT
C
C       THIS SECTION INCLUDES THE EFFECT OF THE DIRECT RADIATION PATH
C THE ANTENNA ELEMENT AT THE RECEIVER
      HR=HR*SQRT2L
      HI=HI*SQRT2L
      TEMP=DELX/(R*R)
      SF=SIN(TEMP2)
      FC=COS(TEMP2)
C
C       CTEMP IS THE COMPLEX GAIN FACTOR INCLUDING ALL RADIATION FROM
C THIS ELEMENT
      CTEMP=CMPLX(-TEMP*SF*HR-HI,TEMP*FC*HR+HI)*.5/LAMBDA
C
C       THIS SECTION ACCUMULATES THE FIELDS OF THE VARIOUS FREQUENCIES
      CFS1=CFS1+CTEMP*CF1(IEL)
      CFS2=CFS2+CTEMP*CF2(IEL)
      CFS3=CFS3+CTEMP*CF3(IEL)
      ALPH=SAK*2.*AZ*RZ/R
      CTEMP=TEMP*.5/LAMBDA*CMPLX(-SF,FC)*
     1CMPLX((1.-COS(ALPH)),-SIN(ALPH))
      CFR1=CFR1+CTEMP*CF1(IEL)
      CFR2=CFR2+CTEMP*CF2(IEL)
      CFR3=CFR3+CTEMP*CF3(IEL)
3     CONTINUE
      WRITE(1,2003) RX,RY,RZ,FT,CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
2003  FORMAT(4F,//,6E13.6,/,6E13.6)
      GO TO 201
C
C       THIS IS THE TERMINATION SECTION.  THE INITIAL RECORD ON
C THE OUTPUT FILE IS WRITTEN AND THE PROGRAM TERMINATES.
200   CALL RELFAS (1)
      CALL EXIT
      STOP
      END
```

CONSTANTS

P	2[illegible]	1	1[illegible]	2	[illegible]	4	[illegible]
S	[illegible]	6	4[illegible]	7	[illegible]	10	[illegible]

COMMONs

XRP	/PLXT	/+0	RXMN	/PLXT	/+1	XAMX	/PLXT	/+2	XRPT	/PLXT	/+3	XRLT	/PLXT	/+4
RYMN	/PLXT	/+5	RYMX	/PLXT	/+6	RYPT	/PLXT	/+7	RYLT	/PLXT	/+10	RZ	/PLXT	/+11
RZMX	/PLXT	/+12	RZPT	/PLXT	/+13	RZLT	/PLXT	/+14	RT	/PLXT	/+15	RI	/PLXT	/+16
RTPT	/PLXT	/+17	RTLT	/PLXT	/+20	AIMN	/PLXT	/+21	AI	/PLXT	/+22	AIPT	/PLXT	/+23
AILT	/PLXT	/+24	ARMN	/PLXT	/+25	ARMX	/PLXT	/+26	ARPT	/PLXT	/+27	ARLT	/PLXT	/+30
ADIN	/PLXT	/+31	ADIX	/PLXT	/+32	ADIP	/PLXT	/+33	ADIT	/PLXT	/+34	ADN	/PLXT	/+35
ADMX	/PLXT	/+36	ADMP	/PLXT	/+37	ADMG	/PLXT	/+40	NR	/PLC	/+0	NI	/PLC	/+1
RZ	/REC	/+2	RT	/REC	/+3	~RITP	/REC	/+4	R	/GROUND	/+0	RI	/GROUND	/+1
ZI	/GROUND	/+25	XZ	/GROUND	/+51	ZZ	/GROUND	/+76	IRI	/GROUND	/+123	AR	/ANT	/+0
AY	/ANT	/+1	AZ	/ANT	/+2	LAMBDA	/ANT	/+3	DAR	/ANT	/+4	CFS1	/ANT	/+5
NR	/VAL	/+0	NI	/VAL	/+1	IPTDAT	/PLXT	/+0						

SUBPROGRAMS

FUNSE.	.JNFP	DFILE	IF	ALPHO.	ALPHI.	PLOUT.	PLINT.	IFILE	NI+0.	RRI+RA.	~.0+1	DMIP	CF.2	S.NI
INPUT	DSQRT	DFM.2	DFM.0	DFA.2	DFM.0	DFMP.2	IOINT	PLOAT	DFA.0	CFS.	SI	CFS	CFI.1	DFA.4
DFS.0	SCAT	CMPLX	CFD.0	CFM.2	CFM.0	FXII								

SCALARS

DPI	6	TAU	1017	HHP	0	A	0	ILM1	1020	
LAMBDA	3	NEL	1021	I	1022	SJMI20	1023	IF.2	1024	
DAR	4	SAR	1025	CFM1	1026	CFM2	1030	CFM3	1042	
CFS1	1034	CFS2	1036	CFS3	1040	M2	1042	IA	0	
RZ	2	IPL	123	AI	0	AY	1	AZ	2	
NELX	1043	DFLT	1045	PI	1	CFI.6	1047	CM	1051	
P	1053	IL	1054	TEMP	1055	P1	1056	P2	1057	
TC	1060	TD	1061	R1	1062	S	1064	C	1066	
SF	1065	FC	1066	HW	0	NI	1	CFI.1	1067	
ALPH	1071	PT	1	NRM+	1	RA+1	2	RRI1	3	
RXLT	4	RYMN	5	RYMX	6	RYPT	7	RYLT	1	
RZMN	11	RZMX	12	RZPT	13	RZLT	14	RT	15	
RTMX	16	RTPT	17	RTLT	20	AIMN	21	AI	22	
AIPT	23	AILT	24	ARMN	25	ARMX	26	ARPT	27	
ARLT	30	ADIN	31	ADIX	32	ADIP	33	ADIT	34	
ADMN	35	ADMX	36	ADMP	37	ADMI	40	SIAR	1	

ARRAYS

ILABL	1072	IPTDAT	0	X	1102	I	1126	Z	1152
CF1	1176	CF2	1246	CF3	1316	RI	1	ZI	25
X2	51	Z2	76						

X1	15	41		
X2	15	41		
Y	10	53	54	90
Z	10	53	54	91
Z1	15	41		
Z2	15	41		

3P	85	148				
200P	65	155				
201P	95	151				
1000P	31	32	39	40	51	52
2000P	48	49				
2001P	46	47				
2003P	149	150				

```
      1          C
      2          C       THIS SUBROUTINE OPENS THE FLIGHT PATH FILE AND INPUTS THE
      3          C FLIGHT PATH PLOT LABEL AND THE INERTIAL TIME CONSTANT
      4          C
      5          C       THIS SUBROUTINE INPUTS THE RECEIVER LOCATION
      6          C COORDINATES OF THE NEXT POINT ON THE FLIGHT PATH.  IF THERE
      7          C ARE NO MORE POINTS THE SUBROUTINE RETS TO THE
      8          C END RETURN POINT
      9                SUBROUTINE IF(ILABL,TAU)
     10                DIMENSION ILABL(8)
     11                COMMON/REC/ DUM(4),NSIZE
     12                CALL JOVSET(1,'PATH.DAT',NS)
     13                WRITE(*,1000) NS
     14           1000 FORMAT(15,' RECORDS IN PATH.DAT',/)
     15                NSIZE=(NS-8)/4
     16                CALL JOVRI(1,ILABL,8,0)
     17                CALL JOVRI(1,TAU,1,0)
     18                RETURN
     19                END
```

CONSTANTS

0	[illegible]	1	5020324444134	2	442w3242u100	4	[illegible]

GLOBAL DUMMIES

ILABL	66	TAU	67

COMMON

DUM	/REC	/+0	NSIZE	/REC	/+4

SUBPROGRAMS

JOVSET INTO, INTI, JOVRI

SCALARS

IF	70	NS	71	NSIZE	4	TAU	67

ARRAYS

ILABL	66	DUM	0

DUM	11		
IF	9		
ILABL	9	10	16
JOVSET	12		
JOVRI	16	17	
NS	12	13	15
NSIZE	11	15	
REC	11		
TAU	9	17	

```
10000P      13      14
```

```
      1                 SUBROUTINE INPUT(S)
      2                 COM O= /REC/ MX(4),NSIZE
      3                 IF(NSIZE .LE. 0) RETURN 1
      4                 CALL JOVNI(1,MX,4,0)
      5                 NSIZE=NSIZE-1
      6                 RETURN
      7                 END

          CONSTANTS

          0       000000000001    1       000000000004    /       000000000000

          COMMON

          MX      /REC    /+0     NSIZE   /REC    /+4

          SUBPROGRAMS

          JOVNI

          SCALARS

          INPUT   36              NSIZE   4

          ARRAYS

          MX      0
```

```
INPUT       1
JOVNI       4
NSIZE       2       3       5
REC         2
MX          2       4
```

```
      C
      C       THIS SUBROUTINE SUMS THE EFFECTS OF THE STRIPS THAT MAKE
      C UP AN GROUND SURFACE.  THERE ARE 'K' STRIPS DESCRIBED IN COMMON
      C GROUND AS FOLLOWS:
      C       X1(I)   THE X-COORDINATE OF THE LEADING EDGE OF THE I'TH STRIP
      C       Z1(I)   THE Z-COORDINATE OF THE LEADING EDGE OF THE I'TH STRIP
      C       X2(I)   THE X-COORDINATE OF THE TRAILING EDGE OF THE I'TH STRIP
      C       Z2(I)   THE Z-COORDINATE OF THE TRAILING EDGE OF THE I'TH STRIP
            SUBROUTINE SCAT
            COMMON /REC/ RX,RY,RZ
            COMMON /ANT/AX,AY,AZ
            COMMON /GROUND/ K,X1(20),Z1(20),X2(20),Z2(20),ILL
            COMMON /SEG/ XX1,ZZ1,XX2,ZZ2,M
      C
      C       THESE ARE INITIAL VALUES FOR THE PARAMETERS USED IN SHADOWING
            SLOPE=1.
            PHIP=1.
      C
      C       THIS IS THE LOOP OVER THE STRIPS
            DO 1 I=1,K
      C
      C       THESE ARE THE VALUES TO BE USED IN THE STRIP
      C INTEGRATION SUBROUTINE
      C       XX1     LEADING X-COORDINATE
      C       ZZ1     LEADING Z-COORDINATE
      C       XX2     TRAILING X-COORDINATE
      C       ZZ2     TRAILING Z-COORDINATE
            XX1=X1(I)
            ZZ1=Z1(I)
            XX2=X2(I)
            ZZ2=Z2(I)
      C
      C       THIS IS A TEST TO SEE IF THE SUMMATION OVER THE GROUND
      C STRIPS HAS REACHED THE RECEIVER LOCATION.  IF IT HAS THE SUMMATION
      C IS STOPPED.  THIS IS TO GIVE THE EFFECT OF FORWARD LOOKING RECEIVER
      C ANTENNA PATTERN.
            IF( XX1 .GE. RX) GO TO 4
      C
      C       IF THE RECIEVER IS LOCATED OVER THE MIDDLE PORTION OF A STRIP
      C THE STRIP WILL BE INTEGRATE ONLY UP TO THE VALUE OF THE
      C RECEIVER X-COORDINATE
            IF(XX2 .LE. RX) GO TO 5
            ZZ2=ZZ1+(RX-XX1)*(ZZ2-ZZ1)/(XX2-XX1)
            XX2=RX
      5     CONTINUE
      C
      C       THIS SECTION DOES THE SHADOWING.  IF PART OR ALL OF THE STRIP
      C IS IN THE SHADOW OF A PREVIOUS STRIP, THIS STRIP WILL BE ELIMINATED
      C OR MASKED TO GIVE THE EFFECT OF SHADOWING.
            DELX=XX2-AX
            IF(DELX .LE. 0.) GO TO 3
            PHIE=(AZ-ZZ2)/DELX
            IF(SLOPE .LT. 0.) GO TO 3
```

```
                IF(PHIL .GE. SLOPE) GO TO 1
                PHIB=(AZ-ZZ1)/(XX1-AX)
                IF( PHIB .LE. SLOPE) GO TO 3
                IF( XX1 .EQ. XX2) GO TO 4
                AB=(ZZ2-ZZ1)/(XX2-XX1)
                BB=ZZ1-AB*(XX1-AX)
                XX1=(AZ-B)/(A-SLOPE)+AX
                ZZ1=-SLOPE*(XX1-AX)+AZ
        4       C
        C         THIS SUBROUTINE WILL INTEGRATE OVER THE STRIP THE
        C CUMPLEX "GAIN" EFFECT OF THIS STRIP WILL BE ADDED TO BE ALL HI
        C IN COMMON "WALL"
        3       CALL SUM
                SLOPE=PHIL
        1       CONTINUE
        6       RETURN
                END
```

CONSTANTS

```
0       20140000000U
```

COMMON

```
BX      /REC    /+0     BY      /REC    /+1     BZ      /REC    /+2     AX      /AIR    /+0     AY      /AIR    /+1
AZ      /ANT    /+2     N       /GROUND/+0      X1      /GROUND/+1      Z1      /GROUND/+25     X2      /GROUND/+51
Z2      /GROUND/+76     IFL     /GROUND/+123    XX1     /SEG    /+0     ZZ1     /SEG    /+1     XX2     /SEG    /+2
ZZZ     /SEG    /+3     N       /SEG    /+4
```

SUBPROGRAMS

SUM

SCALARS

```
SCAI    103             SLOPE   144             PHIB    145             1       146             2       0
XX1     0               ZZ1     1               XX2     2               ZZZ     3               AX      1
DELX    147             AX      0               AZ      2               PHIL    150             A       151
B       152             BY      1               BZ      2               AY      1               146     123
N       4
```

ARRAYS

```
X1      1               Z1      25              X2      51              42      76
```

A	58	59	60							
ANT	11									
AX	11	50	55	59	60	61				
AY	11									
AZ	11	52	55	60	61					
B	58	60								
DELX	50	51	57							
GROUND	12									
I	28	28	29	30	31					
IEL	12									
K	12	20								
N	13									
PHIA	58	58								
PHIE	17	52	54	67						
REC	10									
RX	10	37	42	43	44					
RY	10									
RZ	10									
SCAT	0									
SEG	13									
SLOPZ	14	53	54	56	60	61	67			
SUM	66									
X1	12	28								
X2	12	30								
XX1	13	28	37	42	55	57	58	59	60	61
XX2	13	30	42	43	44	56	57	58		
Z1	12	29								
Z2	12	31								
ZZ1	13	29	43	55	58	59	61			
ZZ2	13	31	43	57	58					

1P	20	54	68	
3P	51	53	56	66
4P	57	61		
5P	42	45		
6P	37	69		

```
C
C       THIS SUBROUTINE INTEGRATES OVER THE SURFACE STRIP DEFINED
C BY X1,Z1,X2,Z2 IN COMMON "SFC", TO GIVE THE FIELD EFFECT
C OF THE ANTENNA ELEMENT IN COMMON "ANT" AT RECEIVER DEFINED
C IN COMMON "RFC".  THE VARIABLES ARE AS FOLLOWS:
C       AX      ANTENNA X-COORDINATE
C       AY      ANTENNA Y-COORDINATE
C       AZ      ANTENNA Z-COORDINATE
C       LAMBDA  WAVELENGTH OF CARRIER
C       AK      T=2*PI/LAMBDA
C       DPI     T=DBLE(PI) (DOUBLE PRECISION)
C       RX      RECEIVER X-COORDINATE
C       RY      RECEIVER Y-COORDINATE
C       RZ      RECEIVER Z-COORDINATE
C       HR      REL PART OF "GAIN" FACTOR
C       HI      IMAGINARY PART OF "GAIN" FACTOR
C       X1      LEADING EDGE OF STRIP'S X-COORDINATE
C       Z1      LEADING Z-COORDINATE
C       X2      TRAILING EDGE X-COORDINATE
C       Z2      TRAILING Z-COORDINATE
C THE INTEGRATION IS PERFORMED BY A MODIFIED TRAPIZOID RULE.
C THE SPACING BETWEEN POINTS ALONG THE VARIABLE OF INTEGRATION
C IS VARIED BY THE RATE OF CHANGE OF THE INTEGRAND.
      SUBROUTINE SUM
      COMMON /SFC/ X1,Z1,X2,Z2,A
      DOUBLE PRECISION A1,A2,B1,B2,XI,AYZ
      REAL  JR,JI,JOR,JOI,JNR,JNI
      REAL LAMBDA
      DOUBLE PRECISION AK,DPI,GR
      COMMON /ANT/AX,AY,AZ,LAMBDA,AK,DPI
      COMMON /RFC/RX,RY,RZ
      COMMON /VAL/HR,HI
      REAL L3,L10
C
C       THIS IS THE INITIALIZATION SECTION
      AYZ=DBLE(AY)+DBLE(AZ)
      AK=SNGL(AK)
      SF=Z2-Z1
      CE=X2-X1
C
C       XMAX IS THE LENGTH ALONG THE SURFACE OF THE STRIP
      XMAX=SQRT(SE*SE+CE*CE)
C
C       THESE ARE THE SIN AND COS OF THE ANGLE THE STRIP MAKES WITH
C A HORIZONTAL PLANE
      SF=SF/XMAX
      CE=CE/XMAX
      JR=0.
      JI=0.
C
C       XI IS THE VARIABLE OF INTEGRATION.  IT IS THE DISTANCE
C ALONG THE SURFACE OF THE STRIP STARTING FROM THE LEADING EDGE
      XI=0.
```

```
      NX=1
      IT=0
C
C       THESE ARE THE LOWER AND UPPER BOUNDS FOR THE SPACING BETWEEN
C POINTS ALONG THE VARIABLE OF INTEGRATION
      L3= LAMBDA/24.
      L10=2.*LAMBDA
      A1=RX-X1
      A2=RX-Z1
      B1=Z1
      B2=Z1-AZ
      A=A1
      TEMP=A2
       A= SQRT(A*A+TEMP*TEMP)
      B=B1
      TEMP=B2
      B= SQRT(B*B+TEMP*TEMP)
      TEMP=A+B
      DR=DSQRT(DBLE(TEMP)*DBLE(TEMP)+DBLE(AY*AY))
      C=DR
      DR=DR*AK
      I=DR/DPI
      F=DR-DBLE(FLOAT(I))*DPI
      C=C/TEMP
      D=C*B
      R=C*A
       S=SQRT((1./A+1./B)/C/C/C)
      G=A1/D/D/R/R/S
      TEMP=G/(AKK*D)
      CF=COS(F)
      SF=SIN(F)
      JOR=G*CF-TEMP*SI
      JOI=G*SF+TEMP*CF
      AP=(-A1*CE-A2*SE)/A
      BP=(B1*CE+B2*SE)/B
C
C       FP IS THE DERIVATIVE OF THE PHASE FUNCTION
C OF THE INTEGRAND
      FP=ABS((AP*BP)/C)
C
C       DL IS DELTA XL
      DL=L3/FP
      IF(DL .GT. L10) DL=L10
      IF(DL .LT. L3) DL=L3
      XL=XL+DL
C
C       THIS IS THE LOOP OVER THE SURFACE OF THE STRIP.  XL IS
C INCREMENTED BY DL (OF VARIABLE SIZE) UNTIL THE END OF THE STRIP
C IS REACHED (XMAX)
    1 CONTINUE
C
C       THIS SECTION CALCULATE VARIOUS TERMS USED IN EVALUATING THE
C INTEGRAND.  THE AMPLITUDE AND PHASE FUNCTION
```

```
C ARE EVALUATED SEPARATELY.  THE DERIVATIVE OF THE PHASE FUNCTION
C IS EVALUATED TO DETERMINE THE SIZE FOR DELTA X
      DLSE=DL*SE
      DLCE=DL*CE
      A1=A1-DLCE
      A2=A2-DLSE
      B1=B1+DLCF
      B2=B2+DLSF
      A=A1
       TEMP=A2
      A= SQRT(A**2+TEMP*TEMP)
      B=B1
      TEMP=B2
      B= SQRT(B**2+TEMP*TEMP)
      TEMP=A*B
      DR=DSQRT(DBLE(TEMP)*DBLE(TEMP)+DBLE(AI*AI))
      C=SNGL(DR)/TEMP
      DR=DR*BK
      I=DK/DPI
C
C       THIS IS THE PHASE ANGLE "MODULO TWO PI"
      F=DK-DBLE(FLOAT(I))*DPI
      D=C**4
      R=C*A
      S=SQRT((1./A+1./B)/C)/C
      G=A1/(D*D*R*S)
C
C       THIS IS THE AMPLITUDE FUNCTION
      TEMP=G/(AK**D)
      CF=COS(F)
      SF=SIN(F)
C
C       THIS IS THE REAL PART OF THE INTEGRAND FOR THE
C INTEGRATION VARIABLE VALUE OF XL
      JNR=G*CF-TEMP*SF
C
C       THIS IS THE IMAGINARY PART
      JNI=G*SF+TEMP*CF
      TEMP=DL
C
C       THESE ARE THE REAL AN IMAGINARY PARTS OF THE THE SUMMATION
C OF THE TRAPIZOIDS MAKING UP THE APPROXIMATION TO THE INTEGRAL.
      JR=JR+(JOR+JNR)*TEMP
      JI=JI+(JOI+JNI)*TEMP
       IF(IT .NE. 0) GO TO 2
      JOR=JNR
      JOI=JNI
      AP=(-A1*CE-A2*SF)/A
       BP=(B1*CE+B2*SE)/B
C
C       FP IS THE DERIVATIVE OF THE PHASE FUNCTION
      FP=ABS((AP*BP)/C)
C
```

```
160             C       DL IS DELTA X AND IS LIMITED BY THE BOUNDS (0,L10
161                   DL=L3/FP
162                   IF(DL .GT. L10) DL=L10
163                   IF(DL .LT. L3) DL=L3
164                   NX=NX+1
165             C
166             C       THE VARIABLE OF INTGRATION IS INCREMENTED AND IF THE END OF THE
167             C STRIP IS REACHED THE LAST TRAPIZOID IS ADDED
168                   XL=XL+DL
169                   IF( XL .LT. XMAX) GO TO 1
170                   DL=XMAX+DL-XL
171                   XL=XMAX
172                   IT=1
173                   GO TO 1
174             C
175             C       THIS SECTION ADDS THE FIELD EFFECT FROM THE STRIP TO THE
176             C TOTAL FIELD SUM AND THEN SUBROUTINE TERMINATES
177             2     CONTINUE
178                   N=NX
179                   TEMP=((Z1-AZ)*CE-X1*SF)/2.
180                   HN=HN+JR*TEMP
181                   HI=HI+JI*TEMP
182                   RETURN
183                   END
```

CONSTANTS

```
D       2056000000000
```

COMMON

```
X1      /SEG    /+0     Z1      /SEG    /+1     X2      /SEG    /+2     Z2      /SEG    /+3     .       /SEG    /+4
AX      /ANT    /+0     AY      /ANT    /+1     AZ      /ANT    /+2     LAMBDA  /ANT    /+3     AR      /ANT    /+4
DPI     /ANT    /+6     PX      /REC    /+0     HY      /REC    /+1     RZ      /REC    /+2     HR      /REC    /+3
HI      /VAL    /+1
```

SUBPROGRAMS

```
DBLE    DFM.0   SNGL    SQRT    DSQRT   DFA.0   DFM*.2  DFD.2   ILIST   FLOAT   DFS.0   DFD.0   COS     SIN     DF*.4
DFM.6   DFA.4   DFD.4   ABS     DFAM.2  DFS.2
```

SCALARS

```
SUM     1064            AY2     1065            AY      1               AAR     1067            AR      *
SE      1070            Z2      3               Z1      1               CF      1071            X2      4
X1      0               XMAX    1072            JR      1073            JI      1074            XL      1075
NX      1077            IT      1100            L3      1101            LAMBDA  3               L10     1102
A1      1103            RA      0               A2      1105            RZ      7               HI      1107
R2      1111            AZ      2               A       1113            TEMP    1114            H       1115
DR      1116            C       1120            I       1121            DPI     0               P       1122
D       1123            R       1124            S       1125            G       1126            CE      1127
SF      1130            JOR     1131            JO1     1132            AP      1133            HP      1134
FP      1135            DL      1136            DLSE    1137            DLCE    1140            JOR     1141
```

A	65	67	73	79	80	87	115	117	121	130	131	154
A1	26	61	65	81	87	111	115	132	154			
A2	24	62	66	87	112	116	154					
AAS	92	154										
AK	29	30	37	74	124							
AKK	37	42	135									
ANT	38											
AP	87	92	154	158								
AZ	30											
AY	30	36	72	122								
AY2	26	36										
AZ	30	64	179									
B	68	70	71	76	80	88	118	120	121	124	131	155
B1	26	63	68	89	113	116	155					
B2	26	64	69	88	114	119	155					
BP	88	92	155	158								
C	73	77	78	79	80	92	123	129	130	131	154	
CE	39	42	47	87	88	110	154	155	174			
CF	83	85	86	136	141	144						
COS	83	136										
D	78	81	82	129	132	135						
DBLE	36	72	76	122	128							
DL	95	96	97	98	109	110	145	101	102	103	104	170
DLCE	110	111	113									
DLBE	109	112	114									
DPI	29	30	75	76	125	126						
DR	28	72	73	74	75	76	122	123	124	125	126	
DSORT	72	122										
E	76	83	84	129	136	137						
FLOAT	76	128										
EP	92	95	158	161								
G	81	82	85	86	132	135	141	144				
HI	32	181										
HR	32	180										
I	75	76	125	128								
II	55	151	172									
JI	27	49	150	181								
JNI	27	144	150	153								
JNR	27	141	149	152								
JOI	27	86	150	153								
JOR	27	85	149	152								
JR	27	48	149	180								
L10	33	60	96	162								
L3	33	59	95	97	161	163						
LAMBDA	28	30	59	60								
M	25	178										
MX	54	164	178									
R	70	81	130	132								
REC	31											
RX	31	61										
RY	31											
RZ	31	62										
S	80	81	131	132								

SE	38	42	46	87	88	109	154	155	174					
SEC	25													
SF	84	85	86	137	141	144								
SIN	84	137												
SNGL	37	123												
SORT	42	47	70	80	117	120	131							
SUM	24													
TEMP	66	67	69	70	71	72	77	82	85	86	110	117	119	120
	121	122	123	135	141	144	145	149	150	179	181	181		
VAL	32													
X1	25	39	61	63	179									
X2	25	39												
XL	26	53	98	148	169	170	171							
XMAX	42	46	47	169	170	171								
Y1	25	38	62	64	179									
Y2	25	38												

1P	103	169	173
2P	151	177	

PROGRAM MOLE.F4

```
      DIMENSION ILABL(8)
      DIMENSION IPTMAT(33)
      COMMON /PLOT/ NMP,MX,MY,MXX,MYY,MXLT,MYMN,MYMX,MYLT,MYLT,
     1PZMN,MZMX,MZFT,MZLT,MTMN,MTMX,MTFT,MTLT,
     2AIMN,AIMX,AIFT,AILT,AMMN,AMMX,AMFT,AMLT,
     3ADIN,ADIX,ADIF,ADIL,
     4AOMN,AOMX,AOMF,AOML
      EQUIVALENCE (IPTMAT(1),NMP)
      IMPLICIT COMPLEX (C)
      DIMENSION X(20),Y(20),Z(20)
      DIMENSION CF1(20),CF2(20),CF3(20)
      IMPLICIT DOUBLE PRECISION (D)
      COMMON /PRC/RX,RY,RZ,RT,MSIZF
      REAL LAMBDA
      COMMON /ANT/AX,AY,AZ,LAMBDA,DAK,DPI
      COMMON /VAL/ MR,MI
      COMMON /GRND/ P(3,4),A(3)
C
C     THIS VALUE OF TWO PI IS INITIALIZED THIS WAY TO AVOID USING
C BLOCK DATA
      DPI=6.2831853071795864769
      WRITE(5,2001)
2001  FORMAT(' INPUT FILE NAME:',$)
      READ(5,2000) ILAB
2000  FORMAT(8A5)
      CALL IFILE(20,ILAB)
      WRITE(5,2002)
2002  FORMAT(' OUTPUT FILE NAME:',$)
      READ(5,2000) ILBL
      CALL OFILE(1,ILBL)
      READ(20,1000) ILABL,TAU
      WRITE(1,1000) ILABL
      DO 3 I=1,2
      READ(20,1000) ILABL
3     WRITE(1,1000) ILABL
1000  FORMAT(8A5,F)
      READ(20) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
      WRITE(1) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
      DAK=DPI/DBLE(LAMBDA)
201   READ(20,2005,END=200) RX,RY,RZ,RT,
     1CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
2005  FORMAT(4F,/,6E13.6,/,6E13.6)
      READ(5,3000) P
3000  FORMAT(3G)
      DO 5 I=1,NEL
      AX=X(I)
      AY=Y(I)
      AZ=Z(I)
      CTEMP=(0.,0.)
      CALL INTR2(CTEMP)
      CT=CTEMP*CF1(I)
      CFR1=CFR1+CT
      CFS1=CFS1+CT
```

```
                CT=CTEMP*CF2(I)
                CFR2=CFR2+CT
                CFS2=CFS2+CT
                CT=CTEMP*CF3(I)
                CFS3=CFS3+CT
                CFR3=CFR3+CT
      5         CONTINUE
                WRITE(1,2005) RX,RY,RZ,RT,CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
                GO TO 201
      C
      C           THIS IS THE TERMINATION SECTION.  THE INITIAL RECORD ON
      C THE OUTPUT FILE IS WRITTEN AND THE PROGRAM TERMINATES.
      200       CALL RELEAS (1)
                CALL EXIT
                STOP
                END
```

CONSTANTS

0	203422877325	1	150042055041	2	000000000024	3	000000000001	4	[illegible]				
5	000000000000												

COMMON

NRP	/PLXT	/+0	RXMN	/PLXT	/+1	RXMX	/PLXT	/+2	RXFT	/PLXT	/+6	RXLT	/PLXT	/+4
RYMN	/PLXT	/+5	RYMX	/PLXT	/+6	RYFT	/PLXT	/+7	RYLT	/PLXT	/+10	RZMN	/PLXT	/+11
RZMX	/PLXT	/+12	RZFT	/PLXT	/+13	RZLT	/PLXT	/+14	RTMN	/PLXT	/+15	RTMX	/PLXT	/+16
RTFT	/PLXT	/+17	RTLT	/PLXT	/+20	AIMN	/PLXT	/+21	AIMX	/PLXT	/+22	AIFT	/PLXT	/+23
AILT	/PLXT	/+24	ARMN	/PLXT	/+25	ARMX	/PLXT	/+26	ARFT	/PLXT	/+27	ARLT	/PLXT	/+30
ADIR	/PLXT	/+31	ADIX	/PLXT	/+32	ADIF	/PLXT	/+33	ADIL	/PLXT	/+34	ADRN	/PLXT	/+35
ADRX	/PLXT	/+36	ADRF	/PLXT	/+37	ADRL	/PLXT	/+40	RX	/REC	/+0	RY	/REC	/+1
RZ	/REC	/+2	CT	/RFC	/+3	NSIZE	/REC	/+4	AX	/ANT	/+0	AY	/ANT	/+1
AZ	/ANT	/+2	LAMBDA	/ANT	/+3	DAR	/ANT	/+4	DPI	/A+1	/+0	RM	/A+1	/+1
NI	/VAL	/+1	P	/GRND	/+0	N	/GRND	/+14	IPTDAT	/PLXT	/+0			

SUBPROGRAMS

FORSE.	.JRFF	ALPHO.	ALPHI.	IFILE	OFILE	FLOUT.	FLINT.	BINARY.	DATE	OPEN.4	I/O.	ARCTN.	LOG2	COS.4
RELEAS	EXIT													

SCALARS

DPI	6	TLBL	361	TAN	364	I	365	LA [illegible]	3
REL	366	DAR	4	RX	0	RY	1	RZ	2
RT	3	CFR1	367	CFR2	371	CFR3	373	CFS1	375
CFS2	377	CFS3	401	AX	0	AY	1	AZ	2
CTEMP	403	CT	405	NRP	0	RXMN	1	RAD	4
RXFT	5	RXLT	6	RXMX	5	RYMN	9	RXFT	7
RYLT	10	RZMN	11	RYMX	12	RZMX	13	RYLT	14
RIMN	15	RTMX	16	RTFT	17	RTLT	20	AI [illegible]	21
AIMX	22	AIFT	23	AILT	24	ARMN	25	RM [illegible]	26
ARFT	27	ARLT	30	ADIR	31	ADIX	32	ADIF	33
ADIL	34	ADRN	35	ADRX	36	ADRF	37	ADRL	40

	HRIZE	4	HR	0	H1	1					
	ARRAYS										
	ILABL	407	IPTDAT	0	I	417	I	443	J	467	
	CE1	513	CF2	563	CF3	633	I	0	J	14	

ADIF	3									
ADIL	4									
ADIP	3									
ADIX	3									
ADRF	3									
ADRL	3									
ADRM	3									
ADRX	3									
AIFI	[illegible]									
AILI	3									
AIMM	3									
AIMX	3									
ANT	15									
ARFT	4									
ARLT	3									
ARMM	3									
ARMX	3									
AX	15	46								
AY	15	47								
AZ	15	48								
CF1	11	37	38	51						
CF2	11	37	38	54						
CF3	11	37	38	57						
CFR1	40	52	61							
CFR2	40	55	61							
CFR3	40	59	61							
CFS1	40	53	61							
CFS2	40	56	61							
CFS3	40	58	61							
CT	51	52	53	54	55	56	57	58	59	
CTEMP	49	50	51	54	57					
DAK	15	39								
DALE	39									
DPI	15	21	39							
EXIT	67									
GRND	17									
HI	16									
HR	16									
I	33	37	38	45	46	47	48	51	54	57
IFILE	26									
ILABL	1	31	32	34	35					
ILBL	24	26	29	30						
INTP2	50									
IPTDAT	2	8								
LAMBDA	14	15	37	38	39					
M	17									
MEL	37	38	45							
MRP	3	8								
NSIZE	13									
OFILE	30									
P	17	43								
PLXT	3									
REC	13									

RELEAS	46			
RT	13	40	41	
RTFT	3			
RTLT	3			
RTMN	3			
RTMX	3			
RX	13	40	41	
RXFT	3			
RXLT	3			
RXMN	3			
RXMX	3			
RY	13	40	41	
RYFT	3			
RYLT	3			
RYMN	3			
RYMX	3			
RZ	13	40	41	
RZFT	3			
RZLT	3			
RZMN	3			
RZMX	3			
TAU	31			
VAL	16			
X	10	37	38	46
Y	10	37	38	47
Z	10	37	38	48

3P	33	35			
5P	45	40			
200P	10	46			
201P	40	42			
1000P	31	32	34	35	46
2000P	24	25	29		
2001P	22	23			
2002P	27	28			
2005P	40	42	41		
3000P	43	44			

```
    1               SUBROUTINE NORMAL(V1,V2,V3,V4,R)
    2               DIMENSION V1(1),V2(1),V3(1),V4(1)
    3               X1=V2(1)-V1(1)
    4               X2=V3(1)-V1(1)
    5               Y1=V2(2)-V1(2)
    6               Y2=V3(2)-V1(2)
    7               Z1=V2(3)-V1(3)
    8               Z2=V3(3)-V1(3)
    9               X=Y1*Z2-Y2*Z1
   10               Y=Z1*X2-Z2*X1
   11               Z=X1*Y2-Y1*X2
   12               R=SQRT(X*X+Y*Y+Z*Z)
   13               V4(1)=X/R
   14               V4(2)=Y/R
   15               V4(3)=Z/R
   16               RETURN
   17               END
```

GLOBAL DUMMIES

V1	133	V2	134	V3	135	V4	136	R	137		

SUBPROGRAMS

SORT

SCALARS

NORMAL	141	X1	142	X2	143	Y1	144	Y2	145		
Z1	146	Z2	147	X	150	Y	151	Z	152		
R	137										

ARRAYS

V1	13	V2	134	V3	135	V4	136				

```
NORMAL          1
R               1       12      13      14      15
SORT           12
V1              1        2       3       4       5       6       7       8
V2              1        2       3       5       7
V3              1        2       4       6       8
V4              1        2      13      14      15
X               9       12      13
Z1              3       10      11
Z2              4       10      11
Y              10       12      14
Y1              5        9      11
Y2              6        9      11
Z              11       12      15
Z1              2        9      10
Z2              8        9      10
```

```
      1               DOUBLE PRECISION FUNCTION DIST(X,Y)
      2               DIMENSION X(1),Y(1)
      3               DOUBLE PRECISION R,TEMP
      4               R=0.
      5               DO 1 I=1,3
      6               TEMP=X(I)-Y(I)
      7             1 R=R+TEMP*TEMP
      8               DIST=DSQRT(R)
      9               RETURN
     10               END
```

GLOBAL DUMMIES

X 56 Y 57

SUBPROGRAMS

DFM.2 DFAM.2 DSQRT

SCALARS

DIST 60 R 62 I 64 TEMP 65

ARRAYS

X 56 Y 57

DIST	1	N		
DSQRT	R			
I	5	6		
R	3	4	7	8
TEMP	3	6	7	
X	1	2	6	
Y	1	2	6	

IP 5 7

PROGRAM INT2.F4

```
      SUBROUTINE INTP2(CTEMP)
      DATA DX,DY/23.,40./
      DIMENSION XTA(3),ZTA(3)
      DOUBLE PRECISION D10,D20,A10,A20
      COMPLEX A,R
      DOUBLE PRECISION DR1,DR2
      COMPLEX CTEMP,CCT,CCX,CCY,CCX0
      REAL N,LAMBDA,N1,N2,N3
      COMMON /GRND/ P(3,4),N(3)
      EQUIVALENCE (N(1),N1),(N(2),N2),(N(3),N3)
      DOUBLE PRECISION DAK,DPI
      COMMON /REC/ XP,YP,ZP
      COMMON /ANT/XA,YA,ZA,LAMBDA,DAK,DPI
      EQUIVALENCE (P11,P(1,1)),(P12,P(1,2)),(P21,P(2,1))
      EQUIVALENCE (P24,P(2,4)),(P31,P(3,1)),(P34,P(3,4))
      LOGICAL TEST
      DATA TEST/.TRUE./
      IF(TEST) CALL NORMAL(P11,P12,P(1,4),N(1),TEMP)
      TEST=.FALSE.
      ZA2=2.*ZA
      TPI=SNGL(DPI)
      AK=SNGL(DAK)
      CTEMP=(0.,0.)
      DELX=DX
      DG0=DIST(D(1,1),D(1,2))
      IX=DG0/DELX
      IF(IX .LT. 0) IX=-IX
      IF(IX .LT. 1) IX=1
      IX=((IX+1)/2)*2
      DELX=DG0/FLOAT(IX)
      XTA(1)=(P(1,2)-P(1,1))/DG0
      XTA(2)=(P(2,2)-P(2,1))/DG0
      XTA(3)=(P(3,2)-P(3,1))/DG0
      DG0X=XTA(1)*DELX
      DG0Y=XTA(2)*DELX
      DG0Z=XTA(3)*DELX
      DG1=DIST(P(1,1),P(1,4))
      DELZ=DY
      IZ=DG1/DELZ
      IF(IZ .LT. 0) IZ=-IZ
      IF(IZ .LT. 1) IZ=1
      IZ=((IZ+1)/2)*2
      DELZ=DG1/FLOAT(IZ)
      ZTA(1)=(P(1,4)-P(1,1))/DG1
      ZTA(2)=(P(2,4)-P(2,1))/DG1
      ZTA(3)=(P(3,4)-P(3,1))/DG1
      DG1X=ZTA(1)*DELZ
      DG1Y=ZTA(2)*DELZ
      DG1Z=ZTA(3)*DELZ
      DO  IXX=1,IX
      FX=FLOAT(IXX)-.5
      XS=P(1,1)+FX*DG0X
      YS=P(2,1)+FX*DG0Y
```

```
      ZS=P(3,1)+FZ*DG0Z
      DO 2 IZZ=1,IZ
      FZ=FLOAT(IZZ)-.5
      XS=XS+FZ*DG1X
      YS=YS+FZ*DG1Y
      ZS=ZS+FZ*DG1Z
      CC6=XR-XS
      CC7=XS-XA
      TEMP=YR-YS
      TEMP2=ZR-ZS
      TEMP3=ZP+ZS
      DR1=DABLE(CC6*CC6)+DABLE(TEMP*TEMP)
      DR2=DR1+DABLE(TEMP3*TEMP3)
      DR1=DR1+DABLE(TEMP2*TEMP2)
      R12=DR1
      R22=DR2
      R10=DSQRT(DR1)
      R20=DSQRT(DR2)
      R1=R10
      R2=R20
      TEMP=YS-YA
      TEMP2=ZS-ZA
      TEMP3=ZS+ZA
      DR1=DABLE(CC7*CC7)+DABLE(TEMP*TEMP)
      DR2=DR1+DABLE(TEMP3*TEMP3)
      DR1=DR1+DABLE(TEMP2*TEMP2)
      D12=DR1
      D22=DR2
      D10=DSQRT(DR1)
      D20=DSQRT(DR2)
      D1=D10
      D2=D20
      F10=R2*XS*(YR-YS)+(R1*XS+R3*(ZS-ZA))*(XR-XS)
      F20=F10+R3*(XR-XS)*ZA2
      COSA=(XTA(1)*CC7+XTA(2)*(YS-YA)+XTA(3)*(ZS-ZA))/D1
      COSA1=(XTA(1)*CC7+XTA(2)*(YS-YA)+XTA(3)*(ZS+ZA))/D2
      COSG=(XTA(1)*CC6+XTA(2)*(YR-YS)+XTA(3)*(ZR-ZS))/R1
      COSG1=(XTA(1)*CC6+XTA(2)*(YR-YS)+XTA(3)*(ZR+ZS))/R2
      COSA=(ZTA(1)*CC7+ZTA(2)*(YS-YA)+ZTA(3)*(ZS-ZA))/D1
      COSA1=(ZTA(1)*CC7+ZTA(2)*(YS-YA)+ZTA(3)*(ZS+ZA))/D2
      COSG=(ZTA(1)*CC6+ZTA(2)*(YR-YS)+ZTA(3)*(ZR-ZS))/R1
      COSG1=(ZTA(1)*CC6+ZTA(2)*(YR-YS)+ZTA(3)*(ZR+ZS))/R2
      CH=COSA-COSG
      CH1=COSA-COSG1
      CH2=COSA1-COSG
      CH3=COSA1-COSG1
      C=COSA-COSG
      C1=COSA-COSD1
      C2=COSA1-COSD
      C3=COSA1-COSD1
      D10=D10*DAK
      D20=D20*DAK
      R10=R10*DAK
```

```
                R20=R20*DAK
                ID=D10/DPI
                D1=D10-DBLE(FLOAT(ID))*DPI
                ID=D20/DPI
                D2=D20-DBLE(FLOAT(ID))*DPI
                ID=R10/DPI
                R1=R10-DBLE(FLOAT(ID))*DPI
                ID=R20/DPI
                R2=R20-DBLE(FLOAT(ID))*DPI
                TEMP=R10*SIN(AK*CH*DELX*.5)*SIN(AK*C*DELZ*.5)/(CH*C*D12*R12)
                CTEMP=CTEMP+TEMP*CEXP(CMPLX(0.,D1*R1))
                TEMP=R10*SIN(AK*CH1*DELX*.5)*SIN(AK*C1*DELZ*.5)/(CH1*C1*D12*R22)
                CTEMP=CTEMP+TEMP*CEXP(CMPLX(0.,D1*R2))
                TEMP=R20*SIN(AK*CH2*DELX*.5)*SIN(AK*C2*DELZ*.5)/(CH2*C2*D22*R12)
                CTEMP=CTEMP+TEMP*CEXP(CMPLX(0.,D2*R1))
                TEMP=R20*SIN(AK*CH3*DELX*.5)*SIN(AK*C3*DELZ*.5)/(CH3*C3*D22*R22)
                CTEMP=CTEMP+TEMP*CEXP(CMPLX(0.,D2*R2))
          2     CONTINUE
          1     CONTINUE
                CTEMP=CTEMP*2./(TPI*TPI)
                ICC=IX*IZ
                RETURN
                END
```

CONSTANTS

0	0000000000000	1	0000000000000	2	0000000000001	3	[illegible]						

GLOBAL DUMMIES

CTEMP 1341

COMMON

R	/GRND	/+0	N	/GRND	/+14	XR	/REC	/+0	YR	/REC	/+1	ZR	/REC	/+2
XA	/ANI	/+0	YA	/ANI	/+1	ZA	/ANI	/+2	LAMBDA	/ANI	/+3	DAK	/ANI	/+4
DPI	/ANI	/+6	N1	/GRND	/+14	N2	/GRND	/+15	N3	/GRND	/+16	[illegible]	/GRND	/+17
P12	/GRND	/+3	P21	/GRND	/+1	P24	/GRND	/+12	P31	/GRND	/+7	P34	/GRND	/+18

SUBPROGRAMS

NORMAL	SNGL	DIST	D	IFIX	FLOAT	DBLE	DFA.0	DFAM.0	DSQRT	DEX.2	DEC.2	[illegible]	[illegible]	[illegible]
SIN	CEXP	CMPLX	CFM.0	CFD.4										

SCALARS

INTR2	1347	DX	1350	DY	1351	TEST	1352	PII	0		
R12	3	TEMP	1353	ZA2	1354	ZA	2	IPI	1355		
DPI	6	AK	1356	DAK	4	CTEMP	1341	[illegible]	1357		
DG0	1360	IX	1361	DG0X	1362	DG01	1363	DG02	1364		
DG1	1365	DELZ	1366	IZ	1367	DG1X	1370	DG11	1371		
DG12	1372	TXX	1373	RX	1374	XS	1375	YS	1376		
ZS	1377	IZZ	1400	RZ	1401	CCR	1402	XM	1		

CC7	1403	XA	0	IH	1	TEMP2	1403	Z#	7
TEMP3	1405	DR1	1406	DR2	1410	H12	1417	H22	1414
H10	1414	P20	1416	H1	1420	H2	1421	YA	1
D12	1422	D22	1423	D10	1424	P20	1426	D1	1430
H2	1431	P10	1432	H2	15	H1	14	D3	16
P20	1433	COSA	1434	COSA1	1435	COSA	1436	COSC1	1437
COSB	1440	COSP1	1441	COSD	1442	COSD1	1443	CH	1444
CH1	1445	CH2	1446	CH3	1447	C	1450	C1	351
C2	1452	C3	1453	ID	1454	ICC	1455	DA-mode	3
P21	1	P24	12	P31	2	P34	13		
ARRAYs									
XTA	1450	ZTA	1401	P	9	H	14		

A	5										
AK	22	116	118	120	122						
AKT	13										
B	5										
C	100	116									
C1	101	118									
C2	102	120									
C3	103	122									
CC6	60	65	90	91	94	95					
CC7	61	77	88	89	92	93					
CCI	7										
CCX	7										
CCXO	7										
CCY	7										
CEXP	117	119	121	123							
CN	96	116									
CN1	97	118									
CN2	98	120									
CN3	99	122									
CMPLX	117	119	121	123							
COSA	88	96	97								
COSA1	89	98	99								
COSB	92	100	101								
COSB1	93	102	103								
COSD	94	100	102								
COSD1	95	101	103								
COSG	90	96	98								
COSG1	91	97	99								
CTEMP	1	7	23	117	119	121	123	126			
D	25										
D1	84	88	92	109	117	119					
D10	4	82	84	104	108	109					
D12	80	116	118								
D2	85	89	93	111	121	123					
D20	4	83	85	105	110	111					
D22	81	120	122								
DAK	11	13	22	104	105	106	107				
DBLE	65	66	67	77	78	79	109	111	113	115	
DELX	24	26	30	34	35	36	116	118	120	122	
DELZ	38	39	43	47	48	49	116	118	120	122	
DG0	25	26	30	31	32	33					
DG0X	34	52									
DG0Y	35	53									
DG0Z	36	54									
DG1	37	39	43	44	45	46					
DG1X	47	57									
DG1Y	48	58									
DG1Z	49	59									
DIST	25	37									
DPI	11	13	21	108	109	110	111	112	113	114	115
DR1	6	65	66	67	68	70	77	78	79	80	82
DR2	6	66	69	71	78	81	83				
DSORT	70	71	82	83							

DX	2	24												
DY	2	38												
F10	86	87	116	118										
F20	87	120	122											
FLOAT	30	43	51	50	109	111	113	115						
FX	51	52	53	54										
FZ	56	57	58	59										
GRND	9													
ICC	127	108	110	111	112	113	114	115						
ID	108													
INTR2	1													
IX	26	27	28	29	30	50	127							
IXX	50	51												
IZ	39	40	41	42	43	55	127							
IZZ	55	56												
LAMBDA	8	13												
N	8	9	10	38										
N1	8	10	86											
N2	8	10	86											
N3	8	10	86	87										
NORMAL	18	14	15	18	31	32	33	37	44	45	50	52	53	54
P	9	18												
P11	14	18												
P12	14													
P21	14													
P24	15													
P31	15													
P34	15													
R1	72	90	94	113	117	121								
R10	4	70	72	106	112	113								
R12	68	116	120											
R2	73	91	95	115	119	123								
R20	4	71	73	107	114	115								
R22	69	118	122											
REC	12													
SIN	116	118	120	122										
SNGL	21	22												
TEMP	10	62	65	74	77	116	117	118	119	120	121	122	123	
TEMP2	63	67	75	79										
TEMP3	64	66	76	78										
TST	16	17	18	19										
TPI	21	126												
XA	13	61												
XR	12	60	86	87										
XS	52	57	60	61	86	87								
XTA	3	31	32	33	34	35	36	88	89	91	91			
YA	13	74	88	89	92	93								
YR	12	62	86	90	91	94	95							
YS	53	58	62	74	86	88	89	90	91	92	93	94	95	
ZA	13	20	75	76	86	88	89	92	93					
ZA2	20	87												
ZR	12	63	64	90	91	94	95							
ZS	54	59	63	64	75	76	86	88	89	90	91	92	93	94

ZTA	95 3	44	45	46	47	48	49	92	93	94	95

1P	50	125
2P	55	124

PROGRAM GLDCDI.F4

```
      1              DIMENSION ILABL(8)
      2              DIMENSION IPTDAT(33)
      3              COMMON /PLOT/ NRP,RXMN,RXMX,RXPI,RXLT,RYMN,RYMX,RYPI,RYLT,
      4             1RZMN,RZMX,RZFT,RZLT,RTMN,RTMX,RTFT,RTLT,
      5             2AIMN,AIMX,AIFT,AILT,ADMN,ADMX,AMFT,AMLT,
      6             3ADIN,ADIX,ADIF,ADIL,
      7             4ADRN,ADRX,ADRF,ADRL
      8              EQUIVALENCE (IPTDAT(1),NRP)
      9              IMPLICIT COMPLEX (C)
     10              DIMENSION X(20),Y(20),Z(20)
     11              DIMENSION CF1(20),CF2(20),CF3(20)
     12              IMPLICIT DOUBLE PRECISION (D)
     13              COMMON /REC/RX,RY,RZ,RT,NSIZE
     14              REAL LAMBDA
     15              COMMON /GROUND/ K,X1(20),Z1(20),X2(0/20),Z2(0/20),IPL
     16              COMMON /ANT/AX,AY,AZ,LAMBDA,PAR,DPI
     17              COMMON /VAL/ NP,MI
     18        C
     19        C       THIS VALUE OF TWO PI IS INITIALIZED THIS WAY TO AVOID USING
     20        C BLOCK DATA
     21              DPI=6.2831853071795864769
     22              WRITE(5,2001)
     23         2001 FORMAT(' INPUT FILE NAME:',$)
     24              READ(5,2000) ILBL
     25         2000 FORMAT(A5)
     26              CALL IFILE(20,ILBL)
     27              WRITE(5,2002)
     28         2002 FORMAT(' OUTPUT FILE NAME:',$)
     29              READ(5,2000) ILBL
     30              CALL OFILE(1,ILBL)
     31              WRITE(1) IPTDAT
     32              READ(20,1000) ILABL,TAU
     33              WRITE(1,1000) ILABL
     34              DO 3 I=1,2
     35              READ(20,1000) ILABL
     36         3    WRITE(1,1000) ILABL
     37         1000 FORMAT(8A5,F)
     38              READ(20) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
     39         201  READ(20,2005,END=200) RX,RY,RZ,RT,
     40             1CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
     41         2005 FORMAT(4F,/,6F13.6,/,6E13.6)
     42        C
     43        C       AFTER THE FIELDS HAVE BEEN ACCUMULATED FOR ALL THE ELEMENTS
     44        C THE CDI'S ARE CALCUATED
     45        C       ACDR    CDI FOR THE GROUND SURFACE
     46        C       ACDI    CDI FOR "IDEAL" GROUND PLANE
     47              ACDR=57.14*REAL((CFR2-CFR3)/CFR1)
     48              ACDI=57.14*REAL((CFS2-CFS3)/CFS1)
     49        C
     50        C       NCRP IS THE COUNT OF THE RECEIVERPOINTS
     51              NRP=NRP+1
     52              IF(NRP .NE. 1) GO TO 4
     53        C
```

```
C       THIS SECTION INITIALIZES THE MAXIMUM AND MINIMUM VALUES
C OF THE VARIOUS RANGE AND DOMAIN VARIABLES.  THESE ARE
C USED IN THE PLOTTING PROGRAM TO SCALE THE PLOTS.  AFTER THE
C RUN IS FINISHED THEY WILL BE OUTPUT IN PLACE OF THE
C INITIAL DUMMY RECORD
      ADDI=ACDI
      ADDR=ACDR
      TO=RT
      ADIX=ACDI
      ADIN=ACDI
      ADIF=ACDI
      ADRX=ACDR
      ADRN=ACDR
      ADRF=ACDR
      RXFT=RX
      RYFT=RY
      RZFT=RZ
      RTFT=RT
      AIFT=ACDI
      ARFT=ACDR
      RXMN=RX
      RXMX=RX
      RYMN=RY
      RYMX=RY
      RZMN=RZ
      RZMX=RZ
      RTMN=RT
      RTMX=RT
      AIMX=ACDI
      AIMN=ACDI
      ARMX=ACDR
      ARMN=ACDR
C
C       THIS SECTION UPDATES THE MAXIMUM AND MINIMUM VALUES
4     CONTINUE
      RXLT=RX
      RYLT=RY
      RZLT=RZ
      RTLT=RT
      AILT=ACDI
      ARLT=ACDR
      IF(RX .LT. RXMN) RXMN=RX
      IF(RX .GT. RXMX) RXMX=RX
      IF(RY .LT. RYMN) RYMN=RY
      IF(RY .GT. RYMX) RYMX=RY
      IF(RZ .GT. RZMX) RZMX=RZ
      IF(RZ .LT. RZMN) RZMN=RZ
      IF(RT .GT. RTMX) RTMX=RT
      IF(RT .LT. RTMN) RTMN=RT
      IF(ACDI .GT. AIMX) AIMX=ACDI
      IF(ACDI .LT. AIMN) AIMN=ACDI
      IF(ACDR .GT. ARMX) ARMX=ACDR
      IF(ACDR .LT. ARMN) ARMN=ACDR
```

```
107                 CONST=EXP((T0-RT)/TAU)
108           C
109           C       THIS  SECTION SIMULATE THE EFFECT OF THE ELECTRICAL AND
110           C MECHANICAL 'INERTIA' OF THE ILS
111           C RECEIVER SYSTEM FOR DYNAMIC SIMULATION
112                 TOMRT
113                 ADDI=CON*(ADDI-ACDI)+ACDI
114                 ADDR=CON*(ADDR-ACDR)+ACDR
115                 IF(ADDI .LT. ADIN) ADIN=ADDI
116                 IF(ADDI .GT. ADIX) ADIX=ADDI
117                 ADIL=ADDI
118                 IF(ADDR .LT. ADRN) ADRN=ADDR
119                 IF(ADDR .GT. ADRX) ADRX=ADDR
120                 ADRL=ADDR
121           C
122           C       THIS IS THE OUTPUT OF THE REAL AND 'IDEAL' , STATIC
123           C AND DYNAMIC CDT'S WWITH THE RECEIVER COORDINATES
124                 WRITE(1,2003) RX,RY,RZ,RT,ACDI,ACDR,ADDI,ADDR
125           2003  FORMAT(8F)
126                 GO TO 201
127           C
128           C       THIS IS THE TERMINATION SECTION,  THE INITIAL RECORD ON
129           C THE OUTPUT FILE IS WRITTEN AND THE PROGRAM TERMINATES.
130           200   CALL RELEAS (1)
131                 ENCODE (9,2006,ILABL(1)) ILBL
132           2006  FORMAT(A5,'.DAT')
133                 CALL DEFINE FILE(1,25,1,ILABL(1))
134                 WRITE(1)1) IPTDAT
135                 CALL RELEAS (1)
136                 CALL EXIT
137                 STOP
138                 END
```

CONSTANTS

```
0       2036220773251   1       1500420550b1    2       0000030000024   3       0.0000000006    4       .12555111459
5       000000000031
```

COMMON

```
WRP     /PLXT   /+0     RXMN    /PLXT   /+1     RXMX    /PLXT   /+2     RXFT    /PLXT   /+3     RXLT    /PLXT   /+4
RYMN    /PLXT   /+5     RYMX    /PLXT   /+6     RYFT    /PLXT   /+7     RYLT    /PLXT   /+8     RZ      /PLXT   /+9
RZMX    /PLXT   /+12    RZFT    /PLXT   /+13    RZLT    /PLXT   /+14    RTMN    /PLXT   /+15    RTMX    /PLXT   /+16
RTFT    /PLXT   /+17    RTLT    /PLXT   /+20    AIMN    /PLXT   /+21    AIMX    /PLXT   /+22    AIFT    /PLXT   /+23
AILT    /PLXT   /+24    ARMN    /PLXT   /+25    ARMX    /PLXT   /+26    ARFT    /PLXT   /+27    ARLT    /PLXT   /+30
ADIN    /PLXT   /+31    ADIX    /PLXT   /+32    ADIF    /PLXT   /+33    ADIL    /PLXT   /+34    ADRN    /PLXT   /+35
ADRX    /PLXT   /+36    ADRF    /PLXT   /+37    ADRL    /PLXT   /+40    RX      /REC    /+0     RY      /REC    /+1
RZ      /REC    /+2     RT      /REC    /+3     RSIZE   /REC    /+4     R       /GROUND/+0      AI      /GROUND/+1
Z1      /GROUND/+25     X2      /GROUND/+51     Z2      /GROUND/+76     IN1     /GROUND/+123    AR      /ANT    /+0
AY      /ANT    /+1     AZ      /ANT    /+2     LAMBDA  /ANT    /+3     DAR     /ANT    /+4     DRI     /ANT    /+5
HR      /VAL    /+0     HI      /VAL    /+1     IPTDAT  /PLXT   /+0
```

SUBPROGRAMS

FORSE.	.JBFF	ALPHD.	ALPHI.	IFILE	OFILE	RINGP.	FLOUT.	FLIST.	FMT.	MEAT	CF.S2	FAT	SP.S2	MEIRAN
VAnDR.	DEFINE	RECNO.	PARAC.	FEIT										
SCALARS														
DPI	6		ILBL	567		TAU	570		1	571				
NEL	572		RX	0		KY	1		NZ	2		NI	3	
CFR1	573		CFR2	575		CFR3	577		CFS1	601		CFS2	603	
CFS3	605		ACON	607		ACO1	610		CNP	1		A_C1	611	
ADDR	612		TO	613		ADIR	32		ADLT	31		ADIP	33	
ADRX	34		ADPX	35		ADNF	37		NPRT	3		PTFT	7	
RZFT	13		RTFI	17		AIFT	23		AMFI	27		IX	1	
RXMX	2		RYMN	5		RIMX	0		NZ1	1		NZ_1	12	
RYMN	15		RIMX	16		AIMX	22		AI_1	21		AM_1	20	
ARMX	25		RILT	4		RILT	10		RZWI	14		NILT	20	
AILT	24		ARLT	30		CON	614		AMIL	34		ANMI	35	
MAIZE	4		K	0		IBL	123		AI	0		NI	1	
AZ	2		DAR	4		MR	0		NI	1				
ARRAYS														
ILABL	614		IPTOAT	0		X	626		Y	652		Y	678	
CF1	722		CF2	772		CF3	1042		X1	1		Y1	25	
X2	51		Z2	76										

OFILE	30												
PLIT	3												
REAL	42	48											
REC	13												
RELEAS	130	135											
RT	13	39	61	71	80	81	92	101	102	107	114	121	
RTFT	3	71											
RTLT	3	92											
RTMM	3	80	102										
RTMX	3	81	101										
RX	13	39	68	74	75	89	95	96	124				
RXFT	3	68											
RXLT	3	89											
RXMM	3	74	95										
RXMX	3	75	96										
RY	13	39	69	76	77	90	97	98	124				
RYFT	3	69											
RYLT	3	90											
RYMM	3	76	97										
RYMX	3	77	98										
RZ	13	39	70	78	79	91	99	100	124				
RZFT	3	70											
RZLT	3	91											
RZMM	3	78	100										
RZMX	3	79	99										
TO	61	107	112										
TAN	32	107											
VAL	17												
X	18	38											
X1	15												
X2	16												
Y	10	38											
Z	10	38											
Z1	15												
Z2	15												

3P	34	36			
4P	52	88			
200P	38	110			
201P	30	120			
1000P	32	33	35	36	37
2000P	24	25	29		
2001P	22	23			
2002P	27	28			
2003P	124	125			
2005P	39	41			
2006P	131	132			

PROGRAM GLDPLT.F4

```
      DIMENSION ITYPE(3,2)
      DATA ITYPE/'STATI','C VAL','UES','SINAD','IC VA','LUES'/
      DATA FID,PRD/'CDID','THEOR'/
      DIMENSION SPACE(4),IAX(2,3)
      DATA SPACE/1.,2.,2.5,5./
      DATA IAX/'DEGRE','ES',' FEET','      ','SECOND','S'/
      DATA PRX,PRY,PRZ,PRT,PAI,PAR/
     1'RX','RY','RZ','RT','CDI','THEO'/
      DIMENSION IPTDAT(33)
      COMMON /PLXIN/NRP,RXMN,RXMX,RXFT,RXLT,RYMN,RYMX,RYFT,RYLT,
     1RZMN,RZMX,RZFT,RZLT,RTMN,RTMX,RTFT,RTLT,
     2AIMN,AIMX,AIFT,AILT,ARMN,ARMX,AMFT,AMLT,
     3ADIN,ADIX,ADIF,ADIL,ADRN,ADRX,ADRF,ADRL
      EQUIVALENCE (IPTDAT(1),NRP)
      DIMENSION ILABL(8)
      DATA XLEN,YLEN,ITIC/20.,8.,21/
      DIMENSION DY1(2000)
      DIMENSION DX(2000),DY(2000)
      NAMELIST /RED/ YLONG,YDEL,YSC,DMIN,DMAX,DEL,IP,XSC
      CALL PLOTS(IBUF,360,6)
    1 WRITE(5,1006)
 1006 FORMAT(' INPUT FILE NAME AND AXIS TYPES:',$)
      READ(5,1005) NAME,ISX,ISY,NOUND
 1005 FORMAT(A5,I,I,F)
      IF(ISY .LT. 1) GO TO 204
      IF(ISY .GT. 2) GO TO 204
      IF(ISX .LT. 1) GO TO 204
      IF(ISX .GT. 3) GO TO 204
      CALL PLOT(0.,-12.,-3)
      CALL PLOT(0.,1.,-3)
      I=0
      CALL IFILE(20,NAME)
      READ(20) IPTDAT
      WRITE(3,1002) NRP
 1002 FORMAT(' THERE ARE',I5,' RECEIVER POINTS.',/)
      WRITE(3,1003)
 1003 FORMAT(14X,'MIN',9X,'MAX',9X,'FIRST',8X,'LAST',/)
 1004 FORMAT(1X,A5,1X,4F12.4)
      WRITE(3,1004) PRX,RXMN,RXMX,RXFT,RXLT
      WRITE(3,1004) PRY,RYMN,RYMX,RYFT,RYLT
      WRITE(3,1004) PRZ,RZMN,RZMX,RZFT,RZLT
      WRITE(3,1004) PRT,RTMN,RTMX,RTFT,RTLT
      WRITE(3,1004) PAI,AIMN,AIMX,AIFT,AILT
      WRITE(3,1004) PAR,AMMN,AMMX,AMFT,AMLT
      WRITE(3,1004) PID,ADIN,ADIX,ADIF,ADIL
      WRITE(3,1004) PRD,ADRN,ADRX,ADRF,ADRL
      GASU=0.
      GASU=0.
      GAC=0.
      DO 7 II=1,3
      READ(20,100) ILABL
      WRITE(3,101) ILABL
  101 FORMAT(1X,8A5)
```

```
      100   FORMAT(8A5)
            CALL SYMBOL(0.,0.,.2,ILABL,90.,40)
      7     CALL PLOT(.3,0.,-3)
            CALL SYMBOL(0.,0.,.2,ITYPE(1,ISY),90.,15)
            CALL PLOT(2.,0.,-3)
      1     READ(20,1000,END=2) X,Y,Z,T,C,M,CD,MD
      1000  FORMAT(8F)
            TEMP=SQRT(X*X+Y*Y)
            IF((TEMP .LT. 3500.) .OR. (TEMP .GT. 20720.)) GO TO 60
            GASU=GASU+C
            GASD=GASD+CD
            GACN=GACN+1.
      60    CONTINUE
            I=I+1
            GO TO (300,301) ISY
      300   CONTINUE
            DY(I)=C
            DY1(I)=R
            GO TO 302
      301   DY(I)=CD
            DY1(I)=RD
      302   CONTINUE
            GO TO (200,201,202) ISX
      200   DX(I)=ATAN2(Z,SQRT(X*X+Y*Y))*57.2953
            GO TO 199
      201   DX(I)=X
            GO TO 199
      202   DX(I)=T
            GO TO 199
      199   IF(I .NE. 1) GO TO 198
            DMIN=DX(I)
            DMAX=DX(I)
      198   DMIN=AMIN1(DMIN,DX(I))
            DMAX=AMAX1(DMAX,DX(I))
      1001  FORMAT(5X,3F)
            IF( I .LT. 2000) GO TO 1
      2     IF(I .LT. 2) GO TO 3
            YLENG=AMAX1(AINX,ABS(BOUND),-AIMN,6.)
            IF(ABS(BOUND) .LT. 1.E-4) GO TO 10
            YDEL=YLENG
            GO TO 11
      10     YLENG=AMAX1(YLENG,ABSX,-ARMN)
            YDEL=FLOAT(IFIX(YLENG/YLEN))
            YLENG=YDEL*YLEN
      11    CALL AXIS(0.,0.,-YLENG,YLENG,YDEL,YLEN,
           1'MICROAMPERES',12,0.,0.,YSC)
            IP=IFIX(ALOG10(DMAX-DMIN))-1
            POW=10.**IP
            DO 120 J=1,4
            DEL=SPACE(J)*POW
            IT=IFIX(DMAX/DEL+1.)+1-IFIX(DMIN/DEL)
            IF(IT .LT. ITIC) GO TO 121
      120   CONTINUE
```

```
      121   DMIN=FLOAT(IFIX(DMIN/DEL))*DEL
            DMAX=FLOAT(IFIX(DMAX/DEL)+1)*DEL
            IP=IP+1
            IF(IP .LT. 0) IP=0
            CALL AXIS3(0.,0.,DMAX,DMIN,DEL,-XLEN,AX(1,ISX),7,36.,0.,XSC)
            CALL PLOT(0.,YLEN/2.,-3)
            CALL PLOT(XLEN,0.,2)
            WRITE(5,PRED)
            CALL PLOT((DX(1)-DMIN)/XSC,DY(1)/YSC,3)
            WRITE(3,1001) DX(1),DY(1),DY1(1)
            GASU=GASU+.7/GACN/150.
            GASD=GASD+.7/GACN/150.
            WRITE(3,1007) GASU,GASD,GACN
     1007   FORMAT(' STATIC MEAN ANGLE ERROR=',E,/
           1' DYNAMIC MEAN ANGLE ERROR=',E,10X,'COUNT=',F4.0)
            DO 4 J=2,1
            WRITE(3,1001) DX(J),DY(J),DY1(J)
      4     CALL PLOT((DX(J)-DMIN)/XSC,DY(J)/YSC,2)
            IF(ROUND .LT. 0.) GO TO 4
            ISW=2
            CALL PLOT((DX(1)-DMIN)/XSC,DY1(1)/YSC,3)
            DO 6 J=2,1
            CALL PLOT((DX(J)-DMIN)/XSC,DY1(J)/YSC,ISW)
      6     ISW=5-ISW
      8     CALL PLOT(XLEN+2.,-5.,-3)
            GO TO 3
     2C4    CALL PLOT(3.,0.,999)
            CALL EXIT
            STOP
            END
```

CONSTANTS

0	0000000000[illegible]	1	0000000000[illegible]	2	2[illegible]	3	[illegible]	4	[illegible]
5	0000000000[illegible]	6	176631463146	7	2[illegible]	10	[illegible]	11	[illegible]
12	0000000000[illegible]	13	202400000000	14	217503600000	15	[illegible]	16	[illegible]
17	204400000000	20	163643334272	21	4[illegible]	22	[illegible]	23	[illegible]
24	0000000000[illegible]	25	0000000000[illegible]14	26	175[illegible]	27	[illegible]	30	[illegible]
31	0000000000[illegible]3	32	200546314631	33	210154000000	34	2[illegible]	35	[illegible]
36	0000000001747								

COMMON

NRP	/PTXXN /+0	RXMN	/PTXXN /+1	RXMX	/PTXXN /+2	RXFT	/PTXX /+3	[illegible]	/PTXX /+4
RYMN	/PTXXN /+5	RYMX	/PTXXN /+6	RYFT	/PTXXN /+7	RYLT	/PTXX /+10	[illegible]	/PTXX /+11
RZMX	/PTXXN /+12	RZFT	/PTXXN /+13	RZLT	/PTXXN /+14	RTMN	/PTXX /+15	[illegible]	/PTXX /+16
RTFT	/PTXXN /+17	RTLT	/PTXXN /+20	AIMN	/PTXXN /+21	AI A	/PTXX /+22	[illegible]	/PTXX /+23
AILT	/PTXXN /+24	AHMN	/PTXXN /+25	ARMX	/PTXXN /+26	AHFT	/PTXX /+27	[illegible]	/PTXX /+30
ADIN	/PTXXN /+31	ADIX	/PTXXN /+32	ADIF	/PTXXN /+33	ALII	/PTXX /+34	[illegible]	/PTXX /+35
ADRX	/PTXXN /+36	ADRF	/PTXXN /+37	ADRI	/PTXXN /+40	IPTLAT	/PTXX /+0		

SUBPROGRAMS

	FORSF. SQRT	.JMFF ATAN2	ALOG10. ATAN	PLOTS AMAX1	ALPHO. ABS	ALPHI. FLOAT	SETP. IFIX	I TF. AXIS3	FLOOT. ALOG10	PLOT. EXP2.2	PLOT IST.	IPLOT EXIT	[illegible]	[illegible]
	SCALARS													
---	PID	1230		pRD	1231		PHX	1232		PWY	1233		[illegible]	1234
	PRT	1235		pAI	1236		PAR	1237		[illegible]	1240		[illegible]	1241
	ITIC	1242		YLENG	1243		YOFL	1244		YSC	1245		[illegible]	1246
	DMAX	1247		DEL	1250		IP	1251		XSC	1252		[illegible]	1253
	NAME	1254		ISX	1255		ISY	1256		[illegible]	1257		I	1260
	NRP	0		RXMA	1		RYMX	2		RXFT	3		[illegible]	4
-----	RIMA	-5		RYMX	6		RYFT	7		RFLT	10		RZ	11
	RZMX	12		RZFT	13		PZLT	14		[illegible]	15		[illegible]	16
	RTFT	17		RTLT	20		AIMA	21		AI-X	22		AIFT	23
	AILT	24		ARMA	25		APMX	26		APFI	27		APLI	30
	ADIM	31		ADIX	32		ADIF	33		ADII	34		AIR	35
	ADRX	36		ADRF	37		AORL	40		GASL	1261		GAS	1262
-----	GACN	1263		II	1264		X	1265		Y	1266		Z	1267
	T	1270		C	1271		M	1272		CU	1273		[illegible]	1274
	TEMP	1275		pOW	1276		J	1277		IT	1300		IS.	1301
-	ARRAYS													
- - - -	IITPE	1302		SPACE	1310		IAX	1314		[illegible]	0		[illegible]	1322
	DY1	1332		DX	5252		DY	11172						

1P	59	89							
2P	59	90							
3P	21	90	132						
4P	122	124							
9P	128	130							
7P	50	56							
8P	125	131							
10P	92	95							
11P	94	98							
60P	62	66							
100P	51	54							
101P	52	53							
120P	102	106							
121P	105	107							
198P	83	86							
199P	78	80	82	83					
200P	76	77							
201P	76	79							
202P	76	81							
204P	25	26	27	28	133				
300P	68	69							
301P	68	73							
302P	72	75							
1000P	58	60							
1001P	88	116	123						
1002P	34	35							
1003P	36	37							
1004P	38	39	40	41	42	43	44	45	46
1005P	23	24							
1006P	21	22							
1007P	119	120							

```
      SUBROUTINE AXIS3(X0,Y0,AMAX,AMIN,DELA,AINCH,NCH,NCK,NEXP,ANG,W1 )
      DIMENSION BCD(1)
      HT = .10
      DELX=SIGN(DELA,(AMAX-AMIN))
      W1=0.
      W2=0.
      W3 = 0.
      NEXP = 0
      NCH=IABS(NCH)
      IF(PWR.NE.0.) NEXP = 6
      CINCH=ABS(AINCH)
      IF(ABS(AMAX-AMIN)+ABS(DELX).LT.1.E-3) GO TO 50
      IF((AMAX-AMIN)/(DELX+1.E-5).GT.3.*CINCH) DELX = (AMAX-AMIN)/(CINCH
      IF(NCH.LT.0) W3 = 1.
      NUM=IFIX((AMAX-AMIN)/DELX+1.9)
      ANC=CINCH/FLOAT(NUM-1)
      IF(AINCH.LT.0.)GO TO 5
      W2=1.
      GO TO 10
    5 W1=1.
   10 CALL PLOT(X0,Y0,3)
      DELG=DELX/10.**PWR/ANC
      ANUM=AMIN-DELX
      X=0.
      Y=0.
      XM=0.
      DO 40 I=1,NUM
      ANUM=ANUM+DELX
      II=0
   25 IF(ABS(ANUM)/10.**II.LT.1.)GO TO 20
      II=II+1
      GO TO 25
   20 IF(ANUM.LT.0.)II=II+1
      IF(ABS(ANUM).LT.1.) II=II+1
      IMORE=NDEC+1
      II=II+IMORE
      IF(IFIX(W1)+1.EQ.1) HT = AMIN1(HT ,ANC/FLOAT(II+2))
      CENTER = FLOAT(II)*HT/(1.+W1)
      OFF = .05
      XC = X - CENTER + W2*(W3*(.30*CENTER) - .15)
      IF(XC.LT.XM)XM=XC
      YC = Y - W1*(HT + .15 - W3*(HT+.3)) - W2*OFF
      CALL PLOT(X0+X,Y0+Y,2)
      CALL PLOT(X0+X+.1*W2,Y0+Y+.1*W1,3)
      CALL PLOT(X0+X-.1*W2,Y0+Y-.1*W1,2)
      CALL NUMBER(X0+XC,Y0+YC,HT,ANUM,0.,NDEC)
      CALL PLOT(X0+X,Y0+Y,3)
      X=X+ANC*W1
      Y=Y+ANC*W2
   40 CONTINUE
      BST = (CINCH - FLOAT(NCH+NEXP)*.12)/2.
      XXC = W1*(X0 + BST) + W2*(X0 + XM - OFF + W3*(2.*CENTER+.44))
      YYC = W1*(Y0 + YC - .17 + W3*(HT + .22) ) + W2*(Y0 + BST)
```

```
54                CALL SYMBOL(XXC,YYC,.12,BCD,90.,0e2,NCH)
55                IF(DUM.EQ.0.) RETURN
56                CALL WHERE (XU,YU,XXCX)
57                CALL SYMBOL(XU,YU,.12,5H  ,90.,0e2,5)
58                CALL WHERE (XU,YU,XXCX)
59                X = XU + (XXC-.08-XO)*M2
60                Y = YU + (YYC+.08-YO)*M1
61                CALL NUMBER(X,Y,.09,PWR,90.,0e2,-1)
62                RETURN
63              50 DELN = 1.5-3010.*PWR/CINCH
64                 N=NCH/5
65                 WRITE(5,1000) AMAX,AMIN,DELA,PWR,(BCD(I),I=1,N)
66           1000 FORMAT(1H0,27HINSUFFICIENT RANGE FOR AXIS ,
67               1/,1X,4G,/,1X,13A5)
68                 CALL EXIT
69                 RETURN
70                 END
```

CONSTANTS

0	175631463146	1	167406111563	2	160517426542	3	2[illegible]	4	[illegible]
5	201400000000	6	174631463146	7	177464146314	10	176431136314	11	[illegible]
12	000000000000	13	175753412172	14	177702436560	15	176534121727	16	[illegible]
17	201244030540	20	000000000000	21	000000000005	22	175507534121	23	175[illegible]

GLOBAL DUMMIES

XO	656	YO	657	AMAX	660	AMIN	661	DELA	662
AINCH	663	BCD	664	NCH	665	NUMC	666	PWR	667
DELN	670								

SUBPROGRAMS

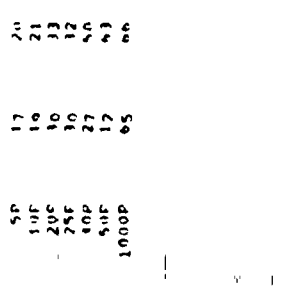
SIGN	IABS	ABS	IFIX	FLOAT	PLOT	EXP3,2	EXP2,2	ALOG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EXIT													

SCALARS

AXIS3	673	HT	674	DELX	675	DELA	676	A [illegible]	677
AMIN	661	W1	676	M2	677	M3	700	[illegible]	701
NCH	702	NCR	665	PWR	667	CINCH	703	[illegible]	704
NUM	704	ANC	705	XO	656	YO	657	I	710
ANUM	706	X	707	Y	710	XP	711	[illegible]	712
II	713	IMORE	714	NDEC	666	CENTER	715	YP	716
XC	717	YC	720	HST	721	XXC	722	YYC	723
XO	724	YO	725	XXCX	726	[illegible]	727		

ARRAYS

BCD	664



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